MAXIM

Data Acquisition Applications Seminar

A/D Converters

Operational Amplifiers

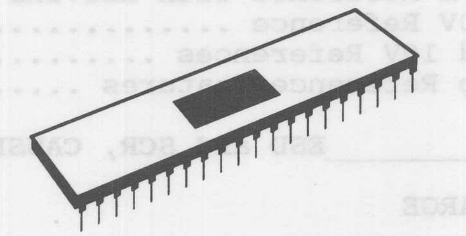
Display Drivers/Counters

Power Supply Circuits

General Purpose Analog Circuits

MAXIM ADVANTAGE

MAXIM



DATA ACQUISITION SEMINAR

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MAXIM ADVANTAGE

MAXIM'S CHARTER

To Become a Full Line Supplier of Analog and Data Acquisition Products

MAXIM ADVANTAGE

MAXIM'S PRODUCT LINE

- A/D Converters
- Operational Amplifiers
- Display Drivers/Counters
- Power Supply Circuits
- Analog Switches
- Filters/Interface Circuits

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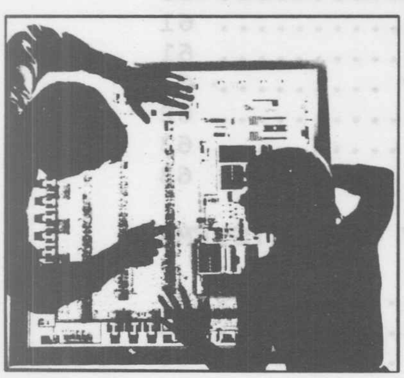
PRODUCT DEVELOPMENT



30+ Products Introduced in 1984

35+ Products Added in 1985

40 More Products Coming in 1986

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MAXIM TECHNOLOGIES

- Silicon Gate CMOS
- 20V Metal Gate CMOS
- 40V Metal Gate CMOS
- 44V Bipolar
- Hybrid
- Thin Film
- Laser Trimming

ADVANTAGE

FOUNDRY BENEFITS

- Multiple wafer fab lines for each technology
- Multiple technologies available
  — Maxim choses best technology for each product
- Controlled by 5 process directors
- Process specifications set by Maxim
- Maxim accepts only "100% to Spec" wafers

ADVANTAGE

MAXIM'S AUDITED RELIABILITY RESULTS

9

FAILURES IN ONE BILLION HOURS

Certified By: Coopers & Lybrand

MAXIM ADVANTAGE

SEMINAR OVERVIEW

- Power Supplies - CMOS for High Efficiency
- SCR and ESD - Causes and Cures
- Integrating A/D Converters
- OP Amps - Chopper Stabilization
- Display Drivers - Minimize μP Overhead
- Switches and Multiplexers
- RS-232 in Single Supply +5V Systems

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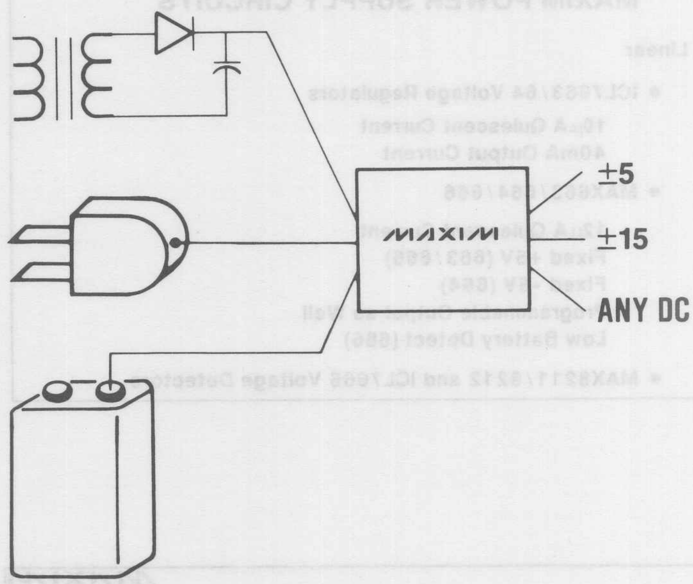
POWER SUPPLY PRODUCTS

- CMOS Linear Regulators
- Power Failure/ Supervisory Circuits
- DC-DC Converters
- 110/220VAC to 5V DC



MAXIM ADVANTAGE

POWER SUPPLY APPLICATION CIRCUITS

- 9V Battery to ±5V
- EEPROM and CMOS RAM Write Protect
- Power Failure Warning and μP Reset
- 3V to 5V DC-DC Converter
- 5V to ±15V
- Battery Life Extension

Maxim has a broad line of power supply circuits, and intends to continue adding new proprietary products which further reduce design effort, circuit complexity and total cost.

Recognizing a need for products in addition to simple three terminal regulators, Maxim has developed regulators with microamp quiescent currents for battery powered applications, DC-DC converters which significantly simplify system design by economically generating different power supply voltages on individual PCBs, and monitoring/supervisory circuits which generate reliable power fail and reset signals.

MAXIM ADVANTAGE

MAXIM POWER SUPPLY CIRCUITS

Linear

- ICL7663/64 Voltage Regulators
  10μA Quiescent Current
  40mA Output Current
- MAX663/664/666
  12μA Quiescent Current
  Fixed +5V (663/666)
  Fixed -5V (664)
  Programmable Output as Well
  Low Battery Detect (666)
- MAX8211/8212 and ICL7665 Voltage Detectors

MAXIM ADVANTAGE

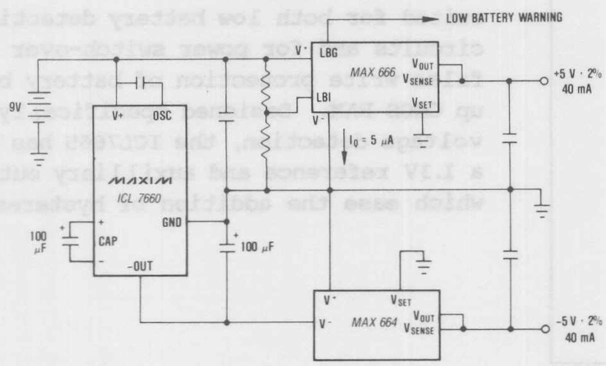
MAX 663/4/6
Voltage Regulators

- Adjustable or Fixed +5V (663)
  -5V (664)
- MAX 663 Positive Regulator
  MAX 664 Negative Regulator
  MAX 666 Positive Regulator with Low Voltage Detect.
- 10μA Quiescent Current
- 40mA Output Current
- 1% Output Voltage Accuracy
- Alternative Output Voltage Available
  Wafer Level Trim, ±2% of Specified Value

The MAX663 and MAX664 are pin compatible upgrades of the ICL7663 and ICL7664, yet have fixed 5V outputs when V_{SET} is grounded. Using Maxim's Dual Mode^{tm} circuitry, the V_{SET} pin also functions like the ICL7663's 1.3V feedback input, which allows the user to select any output voltage using two external resistors if an output voltage other than the internally preset +5V is desired.

The MAX666 is similar to the MAX663 positive voltage regulator, but has a 1.3V comparator which can be used for low battery detection.

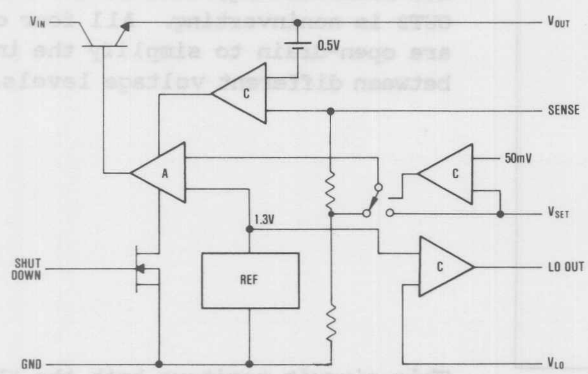
9V BATTERY TO ±5V



The ICL7660 converts the +9V battery voltage to -9V. The MAX666 and MAX664 regulate the ±9V to ±5V while the MAX666 also monitors the 9V battery voltage and issues a Low Battery warning signal when the battery nears its end of life.

The MAX666 and MAX664 draw less than 12uA maximum operating current each, while the ICL7660 typically draws 110uA. For low negative output currents, the ICL7660's operating current can be reduced by adding an external capacitor to lower the internal oscillator frequency. With a 1kHz oscillator frequency, the ICL7660 typically draws 40uA.

MAX 666 BLOCK DIAGRAM



Using only 12uA maximum operating current, the MAX666 can deliver up to 40mA of current via its NPN output stage. Unlike circuits with PNP pass transistors, the NPN base current is delivered to the load for maximum efficiency. The MAX666 dropout voltage is typically 0.8V at 40mA.

Other features that optimize the MAX666 for battery powered systems are the logic level Shutdown input; and the Low Battery comparator.

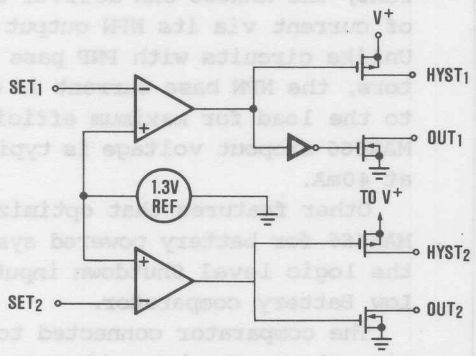
The comparator connected to the V_{SET} pin selects the internal voltage feedback resistors (preset to +5V) when V_{SET} is below 50mV, and routes the V_{SET} input voltage to the feedback error amplifier "A" if the V_{SET} voltage is above 50mV. With this patent pending Dual Mode^{tm} circuit, the MAX666/663/664 can offer both the simplicity and low cost of a fixed output voltage regulator and the flexibility of an externally adjustable regulator, and do so in a compact 8 pin DIP or surface mount package.

ICL 7665
Voltage Detector

- Dual Comparator
- Bandgap Reference
- 10µA Max Supply Current
- Adjustable Hysteresis
- 10nA Max Input Current

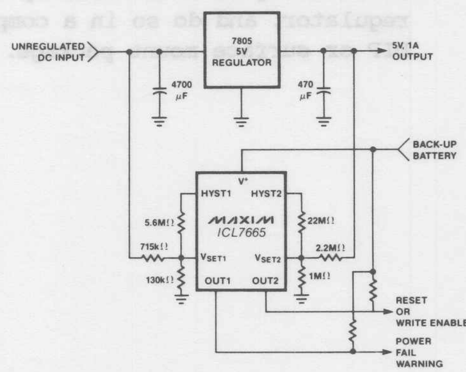
With a guaranteed maximum of 10uA operating current, the ICL7665 is well suited for both low battery detection circuits and for power switch-over and false write protection of battery backed up CMOS RAM. Designed specifically for voltage detection, the ICL7665 has both a 1.3V reference and auxilliary outputs which ease the addition of hysteresis.

ICL7665 BLOCK DIAGRAM



Note that while both hysteresis outputs are noninverting, OUT1 is inverting and OUT2 is noninverting. All four outputs are open-drain to simplify the interface between different voltage levels.

POWER FAIL ALARM WITH RESET



This circuit monitors both the 5V output and the unregulated DC input voltage of a 7805 three terminal regulator. When the unregulated DC input voltage falls below 8.0V, the Power Fail Warning signal goes high. The 7805 will continue to supply +5V for a short period of time, drawing its power from the 4700uF filter capacitor. This gives the uP time to save data in CMOS RAM or EEPROM and to perform an orderly system shutdown. Since the 7805 will deliver a 5V output until its input voltage falls to 7.3V, the 7805 will provide 1A for at least 3.5ms.

When the 5V output falls below 4.5V, the Reset or Write Enable output from the ICL7665 goes low. This signal can be used to reset the uP on power-up, or to gate off the Write and Chip Enable signals to EEPROM and CMOS RAM during power-down.

MAXIM ADVANTAGE

MAX 8211/8212
Micropower Voltage Detectors

Features:

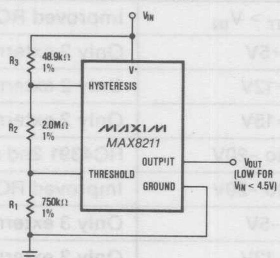
- Improved 2nd Source for ICL8211/8212
- Low Power CMOS Design
- 5μA Quiescent Current
- Onboard Hysteresis Outputs
- $\pm$40mV Threshold Accuracy ($\pm$3.5%)
- 2.0V to 16.5V Supply Voltage Range
- Defined Output Current Limit—MAX8211
- High Output Current Capability—MAX8212

Often used for EEPROM and CMOS RAM memory backup circuits, the MAX8211/12 offer lower operating current and tighter threshold accuracy than the bipolar ICL8211/12.

As single channel versions of the ICL7665, the MAX8211/12 both contain a 1.15V bandgap reference, a voltage comparator, and both hysteresis and logic outputs. The MAX8211 contains a non-inverting comparator while the MAX8212 has an inverting comparator.

MAXIM ADVANTAGE

MAX 8211/8212
Micropower Voltage Detectors



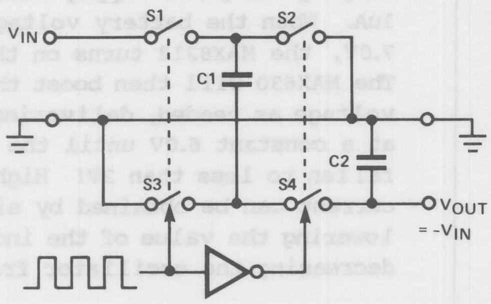
This simplest application generates a signal that goes low whenever the input voltage falls below 4.5V -- useful for generating a reliable uP reset signal during brownouts. The hysteresis output and the 49.9k resistor add 100mV of hysteresis, which prevents repeated switching at the ripple frequency if the output remains near 4.5V during a power brownout.

DC–DC Converter Selection Table

DC-DC Converters

DEVICE	DESCRIPTION	INPUT VOLTAGE	OUTPUT VOLTAGE	COMMENTS
ICL7660	Charge Pump Voltage Inverter	1.5V to 10V	$-V_{IN}$	Not regulated
MAX4193	DC-DC Boost Converter	2.4V to 16.5V	$V_{OUT} > V_{IN}$	RC4193 2nd source
MAX630	DC-DC Boost Converter	2.0V to 16.5V	$V_{OUT} > V_{IN}$	Improved RC4191 2nd source
MAX631	DC-DC Boost Converter	1.5V to 5.6V	+5V	Only 2 external components
MAX632	DC-DC Boost Converter	1.5V to 12.6V	+12V	Only 2 external components
MAX633	DC-DC Boost Converter	1.5V to 15.6V	+15V	Only 2 external components
MAX4391	DC-DC Voltage Inverter	4V to 16.5V	up to −20V	RC4391 2nd source
MAX634	DC-DC Voltage Inverter	2V to 16.5V	up to −20V	Improved RC4391 2nd source
MAX635	DC-DC Voltage Inverter	2V to 16.5V	−5V	Only 3 external components
MAX636	DC-DC Voltage Inverter	2V to 16.5V	−12V	Only 3 external components
MAX637	DC-DC Voltage Inverter	2V to 16.5V	−15V	Only 3 external components
MAX638	DC-DC Voltage Stepdown	3V to 16.5V	$V_{OUT} < V_{IN}$	Only 3 external components
MAX641	High Power Boost Converter	1.5V to 5.6V	+5V	Drives external MOSFET
MAX642	High Power Boost Converter	1.5V to 12.6V	+12V	Drives external MOSFET
MAX643	High Power Boost Converter	1.5V to 15.6V	+15V	Drives external MOSFET

VOLTAGE INVERSION

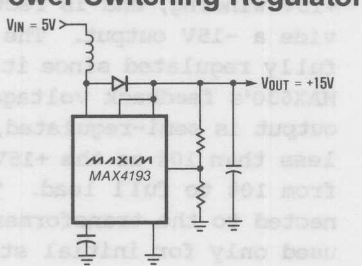


The charge pump voltage inverter of the ICL7660 can best be understood by analyzing this idealized equivalent circuit. When S1 and S3 close, capacitor C1 charges to $+V_{IN}$ on its upper terminal while is lower terminal is connected to ground. During the other phase of the onboard clock, S1 and S3 open, while S2 and S4 close.

When S2 closes, the upper terminal of capacitor C1 is connected to ground, but the capacitor still has voltage across it, and its lower terminal will be at $-V_{IN}$. Switch S4 connects this negative voltage to the output filter, C2.

This widely second sourced IC was invented by Maxim's Dave Bingham in 1977. At Maxim, he has improved his original design by eliminating the need for an external diode, improving its SCR latchup and ESD protections, and by producing a more rugged, reliable device.

MAX 4193
µPower Switching Regulator



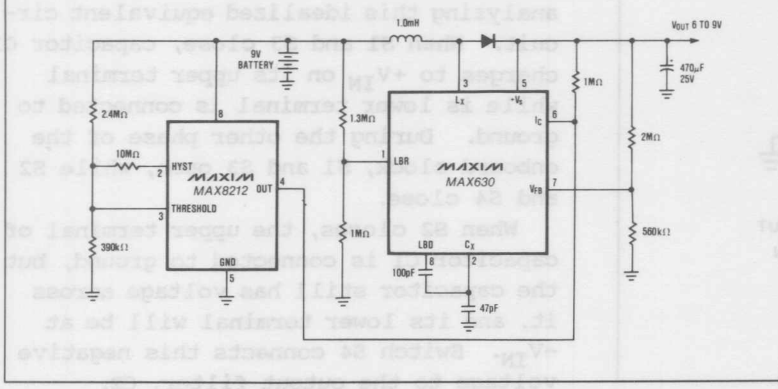
This simple circuit is a complete +5V to +15V DC-DC converter. The MAX630 and MAX4193 have all control circuitry onboard: bandgap reference, output voltage feedback comparator, oscillator, and a 4 ohm N-channel power MOSFET output for driving the inductor.

MAX 630
µPower Switching Regulator

- High Efficiency - 80% Typical
- Low Quiescent Current - 70µA
- Adjustable Output - 1.3V to 15V
- Output Current - 150mA
- Internal Reference - 1.31V
- Remote Shutdown Capability
- Pin and Functionally Equivalent to RC4191/2/3

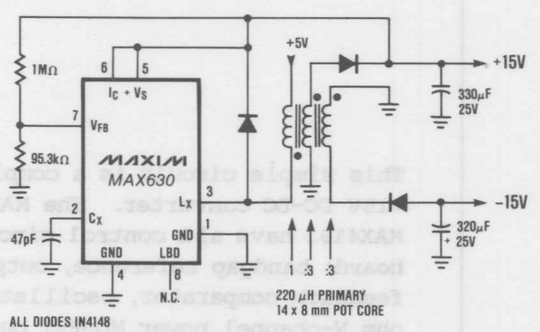
An enhanced version of the MAX4193, the MAX630 has both the low operating current required for battery powered systems, and the simplicity of application desired for local, board level DC-DC power supplies.

BATTERY LIFE EXTENSION DOWN TO 3V IN



When the battery voltage is above 7.0V, the MAX8212 pulls the MAX630 I_C pin low, keeping its power supply current below 1uA. When the battery voltage decays to 7.0V, the MAX8212 turns on the MAX630. The MAX630 will then boost the battery voltage as needed, delivering up to 20mA at a constant 6.0V until the battery has fallen to less than 2V! Higher output current can be obtained by either lowering the value of the inductor or decreasing the oscillator frequency.

+5 VOLTS TO ±15 VOLTS

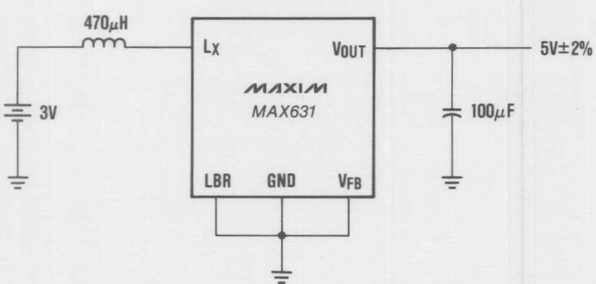


The center winding of the transformer is rectified to provide +15V. The right hand winding is bifilar wound with the +15V winding, and is rectified to provide a -15V output. The +15V output is fully regulated since it supplies the MAX630's feedback voltage. The -15V output is semi-regulated, and will vary less than 10% as the +15V load changes from 10% to full load. The diode connected to the transformer primary is used only for initial startup.

MAX 631/32/33
Boost Converters

- Fixed Output Voltages
  MAX 631 +5V
  MAX 632 +12V
  MAX 633 +15V
  (All Devices can be Externally Programmed)
- Low Quiescent Currect - 90μA
- Output Current - 150mA
- Internal Reference - 1.31V
- Fixed Internal Oscillator - 70KHz
- Only Two External Components
  1 Inductor, 1 Capacitor

3 VOLTS TO 5 VOLTS



The world's simplest DC-DC converter circuit. This is the complete (not a simplified) circuit of a 3V to 5V DC-DC converter. The output current capabilty is 20mA with the 470uH inductor. Decrease the inductor value to increase output current capability.

Use the same circuit with a MAX632 or MAX633 to get a +12V (MAX632) or +15V (MAX633) output.

MAX 634
μPower Inverting Switching Regulator

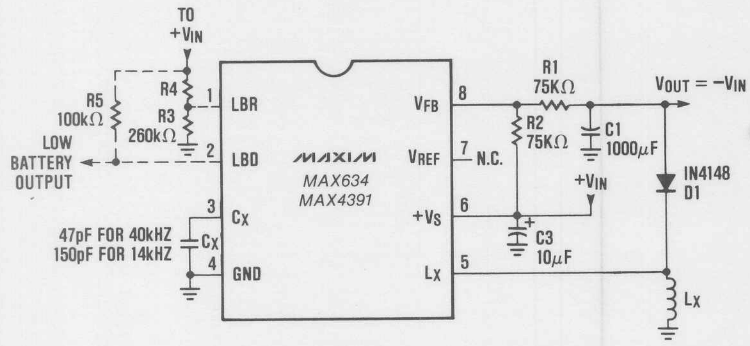
- Convert Positive Voltage into a Negative Voltage
- Adjustable Output Voltage
- High Switch Current Capability - 150mA
- Low Quiescent Supply Current - 150μA
- Low Battery Detection Circuitry
- V_{in} to V_{out} Guaranteed to 25V

The MAX634 is an enhanced CMOS version of the bipolar RC4391 inverting switching regulator, with lower operating current and improved output voltage accuracy.

The basic operating circuit requires only two external resistors, an inductor, a diode, and three capacitors.

MAXIM ADVANTAGE

REGULATED VOLTAGE INVERTER



This circuit performs the same function as an ICL7660, but has 0.5% load regulation and will deliver up to 250mW of output power.

The MAX634 pulses the L_X pin as needed to keep the V_{FB} terminal at zero volts. With R1 equal to R2, the negative output voltage is equal to the positive input voltage.

For a fixed output voltage, connect the lower end of R2 to the +1.25V V_{REF} output rather than to the input voltage.

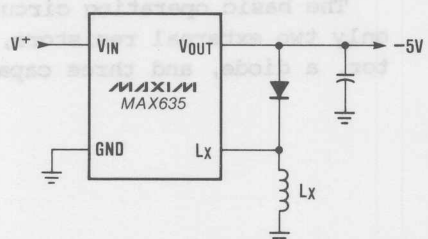
MAXIM ADVANTAGE

MAX 635/6/7
Inverting Converters

- Fixed Output Voltages
  MAX 635 -5V
  MAX 636 -12V
  MAX 637 -15V
  (All Devices can be Externally Programmed)
- Low Quiescent Current - 90μA
- Internal Reference - 1.31V
- Low Battery Detection
- High Switch Current Capability
- Fixed Internal Oscillator - 70KHz
- Only Three External Components
  1 Inductor, 1 Capacitor, 1 Diode

MAXIM ADVANTAGE

MAX635 +V to -5V Minimum Parts Inverter



Use an identical circuit with the MAX636 or MAX637 to produce -12V (MAX636) or -15V (MAX637).

MAXIM ADVANTAGE

MAX 638
Step-Down Converter

- +15V to +5V Converter
- Low Quiescent Current - 90μA
- High Efficiency - 80% Typical
- Adjustable Output Voltage 2 External Resistors
- Remote Shutdown
- Internal Reference - 1.31V
- Alternative Output Voltages Available Wafer Level Trim, ±2% of Specified Values

The high efficiency MAX638 beats even low-dropout series pass regulators for high efficiency conversion of a 12V or 9V battery to +5V and lower output voltages, at currents from 2mA to 40mA.

MAXIM ADVANTAGE

MAX641/42/43
High Power Boost Converters

- Fixed Output 5, 12, and 15V
- Minimum External Components
- No Output Programming Resistors
- Drives External MOSFET Directly
- Micropower Stand-by Operation

The onchip power FET of the MAX631/32/33 and MAX641/42/43 is suitable for output power levels up to about 250mW. For higher output power, the MAX641/42/43 can directly drive the gate of an external power MOSFET. The MAX641/42/43 are intended for DC-DC converters up to the 10 watt level.

MAXIM ADVANTAGE

INDUCTOR FEATURES

- Molded Coils
  - Low Cost
  - Resistor Size
  - Low Efficiency
- Potted Toriods
  - High Efficiency
  - High Cost
- Pot Cores
  - High Efficiency
  - Winding Versatility
- Toroidal Cores
  - Lightest Weight
  - Low Core Cost
  - High Winding Cost

See the MAX630 data sheet for further information about inductors.

Coil and Core Manufacturers

MANUFACTURER	TYPICAL PART #	DESCRIPTION
MOLDED INDUCTORS		
Dale	IHA-104	500μH, 0.5 ohms
Nytronics	WEE-470	470μH, 10 ohms
TRW	LL-500	500μH, 0.75 ohms
POTTED TOROIDAL INDUCTORS		
Dale	TE-3Q4TA	1mH, 0.82 ohms
TRW	MH-1	600μH, 1.9 ohms
Torotel Prod.	PT 53-18	500μH, 5 ohms,
FERRITE CORES AND TOROIDS		
Allen Bradley	T0451S100A	Tor. Core, 500nH/T^2
Siemens	B64290-K38-X38	Tor. Core, 4μH/T^2
Magnetics	555130	Tor. Core, 53nH/T^2
Stackpole	57-3215	Pot Core, 14mm x 8mm
Magnetics	G-41408-25	Pot Core, 14 x 8, 250nH/T^2

Note: This list does not constitute an endorsement by Maxim Integrated Products and is not intended to be a comprehensive list of all manufacturers of these components.

MAXIM ADVANTAGE

MAXIM POWER SUPPLY CIRCUITS

AC-to-DC

- MAX610/600 110-220VAC Full Wave AC to DC
- MAX611/601 110-220VAC Half Full AC to DC
- MAX612/602 8VAC Full Wave AC to DC

Voltage References

- AD2700/2701/2710 Super Precision Reference
- MAX670/671 Kelvin Precision Reference
- REF01/REF02 +10V/+5V Reference
- ICL8069 1.2V Low Power Bandgap

MAXIM ADVANTAGE

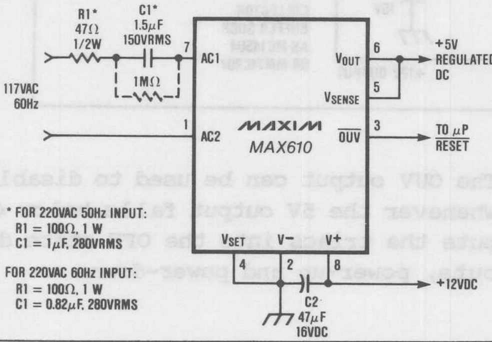
MAX 610/11/12
AC to DC Regulator

- 110/220 VAC to 5V DC
- Only 3 External Components
- Transformer is Optional
- 50 mA Output
- On-board Bridge Rectifier
- On-board 12V Zener
- Series Pass Regulator
- Over/Under Voltage Detector
- Power-up Reset Delay Programmed by External Capacitor

The MAX611/601 have a half wave rectifier which allows the negative side of the 5V and 12V outputs to be connected directly to one side of the power line and to the MT1 of triacs. The MAX612 and MAX602 are intended for use in isolated power supplies using an 8VAC transformer. The MAX610/600 rectify both halves of the input waveform, thereby reducing the value of the series current limiting capacitor required for a given output current. **Unlike the MAX611/601, the output of the MAX610/600 cannot be connected to one side of the power line.**

MAXIM ADVANTAGE

MAX610/MAX600
Simplest Line Powered 5V Supply

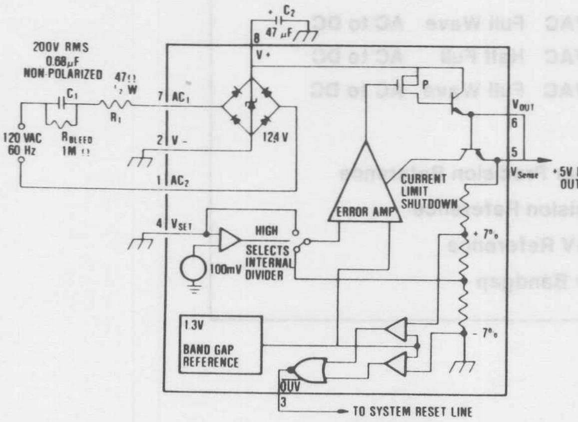


The output of this power supply is NOT ISOLATED from the power line. **The MAX610 and any equipment powered by the MAX610 must be enclosed to avoid electrical shock hazards.** This circuit will deliver 50mA at 5V.

The OUV output goes low whenever the output voltage falls below 4.65V. This signal can be used to reset a microprocessor or other circuitry during brownouts, power-up, and power-down.

MAXIM ADVANTAGE

MAX 610

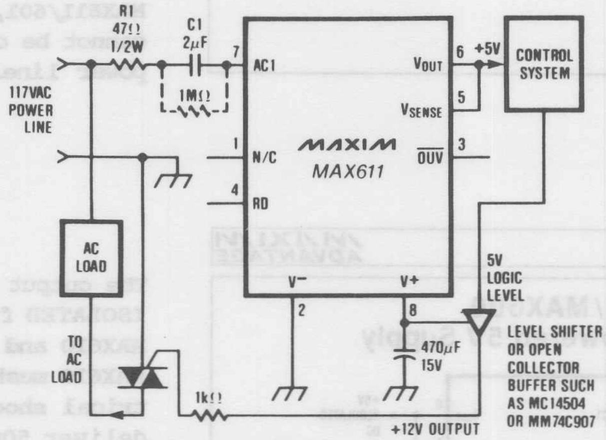


The capacitor C1, connected to the 120VAC input, reactively limits the current to 40mA/uF at 120VAC and 60Hz. The MAX610 rectifies the input, and the zener shunt regulates the current limited input voltage to 12.4V. This voltage is stored on C2 (47uF).

The series pass regulator, similar to that of the MAX663, regulates the 12.4V down to 5V.

MAXIM ADVANTAGE

DRIVING TRIACS



Note that V^- is tied to the same point as one side of the power line and the MT1 of the triac. The 12V output at the MAX611 V^+ is used to provide a high level drive for the triac gate.

The OUV output can be used to disable the triacs whenever the 5V output falls below 4.65V. This puts the triacs into the OFF state during brown-outs, power-up and power-down.

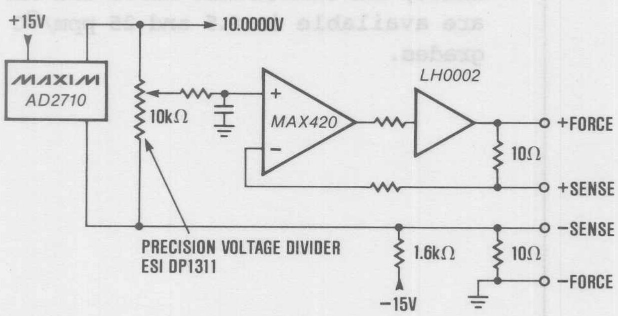
AD2700/2701/2710
Precision Voltage References

- Pin for Pin 2nd Source for Analog Devices
- Excellent Initial Accuracy
  AD2700/2701 +/-10V ±2.5mV
  AD2710 +10V ±1mV
- Low Temperature Coefficient
  AD2700/01 3ppm/°C
  AD2710 1ppm/°C
- Long Term Stability, 50ppm/1000hrs
- Low Noise, 6μVp-p typ.
- 10mA Output Current
- Load Regulation - 50μV/mA max
- Line Regulation - 100μV/V

The AD2710 achieves a 1ppm voltage temperature coefficient via ultra-stable zeners, and laser trimming of both the initial voltage and tempco. It does NOT use a heated substrate, which degrades the long term stability. The long term stability is 50ppm at 50^{O}C.

VARIABLE PRECISION REFERENCE WITH AD2710

• No Trims • Buffered Output • Kelvin Sensing • 0.1mV Resolution



An AD2710 reference and a precision voltage divider combine to make a 0 to 10.000V variable reference that requires no trimming. A MAX420 "no-drift" op-amp and LH0002 buffer provide Kelvin sensed outputs. Using the ESI divider shown, the reference is settable in 100uV steps.

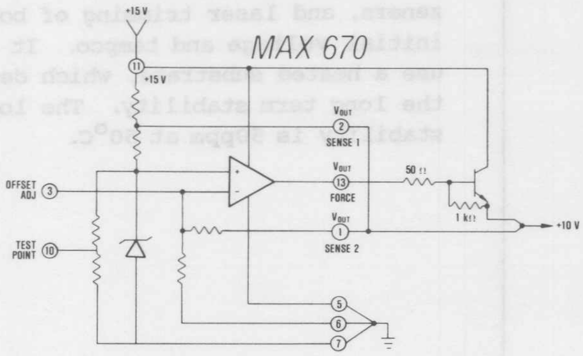
MAX670/671
Kelvin Precision References

- Precision +10V, 1 ppm/°C (MAX671)
- Force+Sense for V_{OUT} and Gnd
- Excellent Line and Load Regulation
- ±10mA Output Current Capability
- Low Noise, 6μV p-p
- Increased Current Capability with Stability and Accuracy Maintained
- 14 Pin Sidebrazed Ceramic

The AD2710 is an excellent 1ppm reference provided the load current is constant. Unfortuately, load current changes rapidly degrade its output accuracy. For example, a 5mA change in load current in only 20 milli-ohms of resistance between the AD2710 and its load will result in a 10ppm change in the output voltage. The MAX670/671 eliminate these errors by adding Kelvin connections (also called remote sensing) to both the output and ground of the AD2710.

HIGH CURRENT 10V REFERENCE

MAX 670



In addition to solving the problem of delivering a stable voltage at the point of use, the Kelvin sense pins of the MAX670/671 enable the design of other circuits, such as this high current reference. The external NPN transistor boosts the maximum output current to over 100mA while significantly improving the load regulation and output impedance.

REF01/02
Voltage References

- Precision Output Voltage
  - REF01 +10V ±0.3%
  - REF02 +5V ±0.3%
- Adjustment Range
  - REF01 ±3%
  - REF02 ±6%
- Low Noise
  - REF01 $20\mu V_{p-p}$
  - REF02 $10\mu V_{p-p}$
- Wide Input Voltage Range, (V_{out} +3V) to 33V
- Low Supply Current - 1.4mA max
- High Load Driving Capability - 20mA
- Pin for Pin 2nd Source

Situated midway between the AD2700 and the ICL8069 in both price and performance, the monolithic REF01 and REF02 are available in 8.5 and 25 ppm/^{o}C grades.

ICL 8069
Low Voltage Reference

- 1.2V Temperature Compensated
- Low Bias Current - 50μA Min.
- Low Dynamic Impedence - 1Ω Typ
- 5mA Maximum Current
- Low Noise, 10Hz to 10KHz - 5μV

A low cost 2-terminal, 1.23V reference with available temperature coefficients ranging from 10ppm (A suffix) to 100ppm (D suffix).

MAXIM ADVANTAGE

ESD / SCR

CAUSES / PREVENTION

ESD SYMPTOMS

- High Reject Rate in Production
- Increased Rejects in Winter and Dry Weather
- Inputs Shorted to V^+ or V^-
- High Input Leakage
- Latent Field Failures

ESD damage often appears as a 1mA to 20mA short between an input and V^+. Since low humidity increases the voltage of most static generators, ESD failures tend to occur more often in dry weather. Since heating cold air reduces its relative humidity, ESD problems are also generally most severe in Winter.

In addition to causing immediate failures, ESD can cause reliability problems since partial ESD failures may pass board level tests, and then later fail at the end user's location.

ESD CURES

- Better IC Design
  Maxim's Target: 2000V per 883C, Method 3015.2
- Antistatic Material
  Tubes, Foam, Benchtops, Tote Boxes
- Proper Handling
  Grounded Wriststraps, Use Antistatic Material

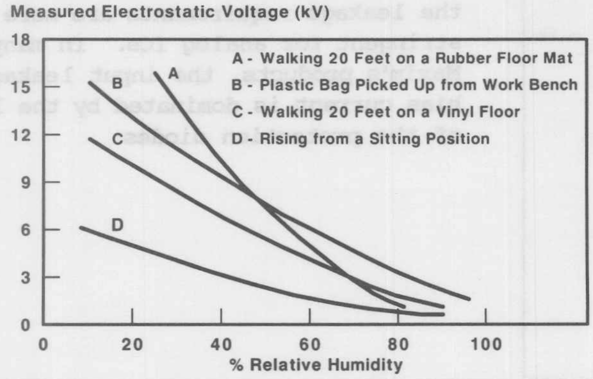
Maxim designs in ESD protection from the start. We have a corporate goal of at least 2000V protection on all device pins, with particular emphasis on the corner pins, since these are the pins most often handled and "zapped". We have chosen 2000V as the target because that is the level specified for Class B designation by Mil Std 883, and because it is relatively easy to keep ESD static levels below 2000V by using simple precautions.

TYPICAL ESD GENERATORS

Means of Static Generation	Relative Humidity Low, 10-20%	Relative Humidity High, 65-90%
Walking Across Carpet	35,000V	1500V
Walking Over Vinyl Floor	12,000V	250V
Working at Bench	6000V	100V
Vinyl Envelopes for Work Instructions	7000V	600V
Common Poly Bag Picked up from Bench	20,000V	1200V
Work Chair Padded with Urethane Foam	18,000V	1500V

The 35kV developed by walking across a carpet in a dry environment is sufficient to destroy even bipolar TTL logic circuits. On the other hand, it is rare to see ESD voltages above 2000V when the relative humidity is high. "A Model for the Failure of Bipolar Silicon Integrated Circuits Subjected to ESD," 12th Annual Proceedings of Reliability Physics, 1974 by T.S. Speakman and "Gate Protection of MOS Devices," IEEE Transactions on Electronic Devices, ED-18, No. 4, April 1971 by M. Lenzlinger, are good references for further information on both the levels generated by various ESD sources and methods of controlling the generation of ESD potentials.

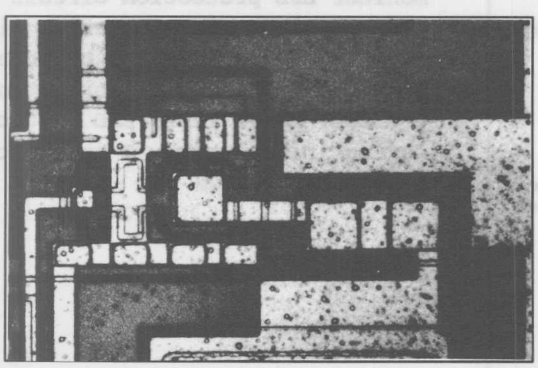
ELECTROSTATIC VOLTAGE VS. HUMIDITY



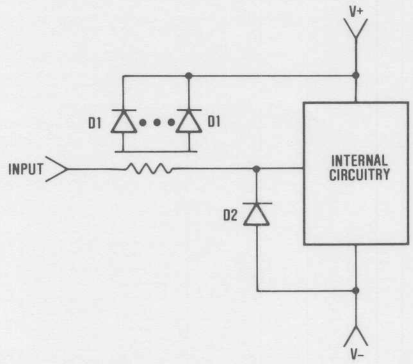
ESD CLASSIFICATIONS

VOLTAGE	MIL-STD-883C	SENSITIVITY
0-1000V	Class A	Extraordinarily prone to damage. Failures occur even observing all precautions.
1000V-2000V	Class A	Prone to damage. All ESD precautions must be strictly observed.
Above 2001V	Class B	MIL-STD-883C does not require ESD warning stickers. No ESD damage with reasonable precautions.

MAXIM ESD PROTECTION

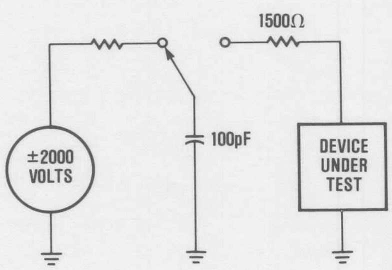


MAXIM'S ESD PROTECTION



ESD protection of analog ICs is more difficult than with digital logic, since the leakage requirements are more stringent for analog ICs. In many of Maxim's products, the input leakage or bias current is dominated by the leakage of the protection diodes.

ESD TEST CIRCUIT
Mil STD 883C, Method 3015.2



This test circuit simulates a person charged to 2000V touching an IC. The 100pF value was established in Mil STD 883 as the typical capacitance between a person and earth ground. Later studies have indicated a slighly higher capacitance and lower equivalent series resistance, but the 100pF, 1.5 kilohm standard is well established and gives good relative comparisons of the level of ESD protection of an IC.

STATIC CONTROL VENDORS

	3M	Olympic Plastics	Semtronics	IMCS
• Handling Protection				
Containers, Mats, Straps	•	•	•	
Air Ionizers	•	•	•	
• Test Equipment				
Potential Field Measurement	•		•	•
Discharge Sensitivity Systems				•
• Packaging	•	•	•	
• Training	•			

IMCS, Mountain View, CA 94043, 415/964-4090
Semtronics, Scotch Plains, NJ 07076, 201/561-9520
3M/Static Control Systems, St. Paul, MN 55144, 612/452-5300
Olympic Plastics, Los Angeles, CA 90016, 213/837-5321

Maxim uses an IMCS Model 2400B tester to monitor ESD protection circuit performance. Since ESD protection circuitry performance is affected by both the design and the wafer fabrication process, Maxim tests ESD protection both during initial product introduction and weekly QA checks.

SCR LATCHUP

Symptoms

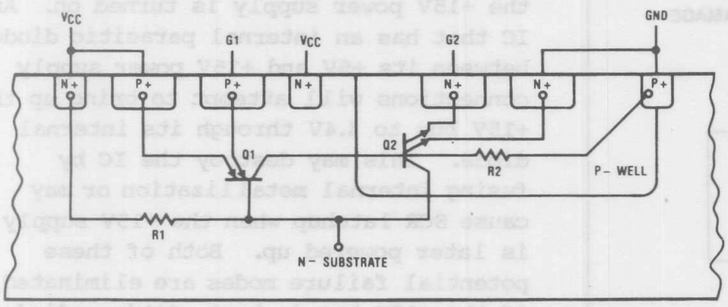
- High Current, V^+ to V^- Short
- Catastrophic Failure

Causes

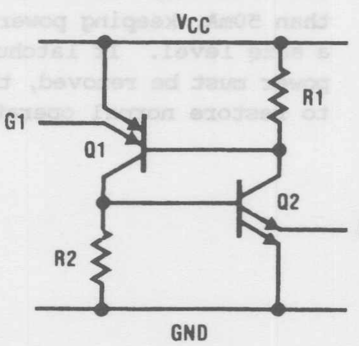
- Applying Input Voltages Higher than V^+ or Below V^-
- Very Fast Rate-Of-Rise on V^+ (dV/dT)
- Improper Power Supply Sequencing

In most cases, a latched IC gets HOT! Easy to identify if it occurs, SCR latchup is also easy to avoid by following simple circuit design precautions. Most latchup problems are caused by failure to observe Absolute Maximum Ratings -- usually by driving an input above V^+ or below V^-. When this cannot be avoided, limiting the over-drive current to less than 10mA will prevent SCR latchup. Nevertheless, as little as 1mA of current injected into on-chip input protection diodes, without causing device latchup or damage, may interfere with normal operation.

SCR MECHANISM



SCR MECHANISM



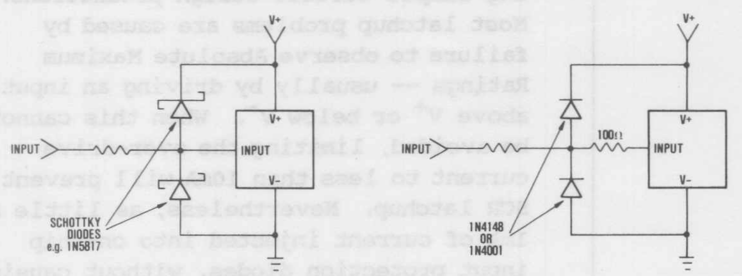
This cross-sectional diagram of a P-well CMOS IC shows a typical parasitic SCR structure. The schematic below shows the equivalent circuit.

Analysis of this circuit shows that there are two stable states, OFF and ON. In the desired state both Q1 and Q2 are off. In the undesired state, both Q1 and Q2 are ON or "latched up". Latchup occurs when the product of the NPN and PNP beta is greater than 1, and enough current flows through R1 and R2 to develop 0.6V (one V_{BE}) across the resistors. The latchup is triggered by current injected into the terminals G1 and G2, which represent parasitic diodes and the diodes purposely designed into the IC for ESD protection.

The IC designer reduces the sensitivity to SCR latchup by careful layout techniques which lower the betas of the transistors and the value of R1 and R2, thereby increasing the trigger current required for SCR latchup.

In many cases, Maxim has lowered the PNP beta such that latchup cannot occur with any level of trigger current. In other cases we design such that latchup will not occur with less 50mA of input current.

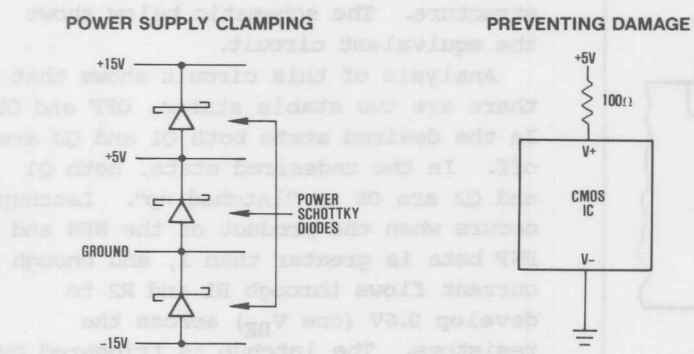
PREVENTING SCR LATCHUP VIA INPUT PROTECTION



Schottky diodes clamp the input voltage to 0.4V, which is less than the 0.6V forward voltage of the internal diodes. Therefore no input current flows and latchup will not occur.

In the second circuit, standard diodes clamp the input signal. The 100 ohm resistor between the diodes and the IC input limits the current into the parasitic diodes to a safe level, preventing SCR latchup.

PREVENTING SCR LATCHUP



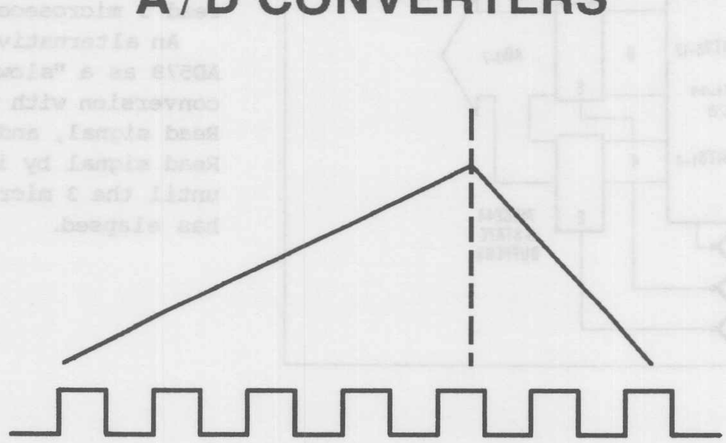
One of the most common methods of damaging ICs is to power up the +5V before the +15V power supply is turned on. An IC that has an internal parasitic diode between its +5V and +15V power supply connections will attempt to bring up the +15V bus to 4.4V through its internal diode. This may destroy the IC by fusing internal metallization or may cause SCR latchup when the +15V supply is later powered up. Both of these potential failure modes are eliminated if the +15V bus is kept within a diode drop of the +5V supply by a power Schottky diode connected between the +5V and +15V busses. The other two diodes shown prevent other similar potential fault conditions.

The right hand circuit is a simple method of preventing destruction of an IC in those rare cases where latchup cannot be prevented. The 100 ohm resistor will limit fault current to less than 50mA, keeping power dissipation to a safe level. If latchup occurs, the power must be removed, then re-applied to restore normal operation.

SCR SENSITIVITY

MAXIM:	**50mA Standard. Verified during new product qualification**
COMPETITION:	**5mA to 10mA SCR sensitivity on many devices**

A / D CONVERTERS



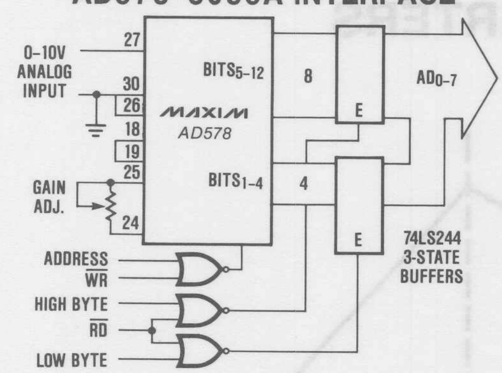
AD578
3μs 12 Bit A/D Converter

Features:

- Fast Conversion: 3μs (AD578L)
- Internal Reference
- Low Gain TC: 30ppm/°C max.
- Linearity Error .012% max.
- No Missing Codes Over Temperature
- Parallel and Serial Outputs
- Adjustable Internal Clock
- Short Cycle Capability
- Pin-for-Pin 2nd Source

The AD578 can provide 300,000 12 bit A/D conversion results each second, suitable for digitizing analog signals up to 150kHz bandwidth. Alternatively, the AD578 can be used with multiplexers to monitor several lower bandwidth signals.

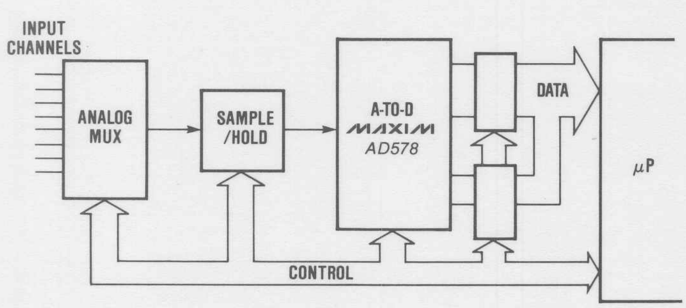
AD578-8085A INTERFACE



In this circuit, the AD578 conversion is started by a Write pulse. Data can be read 3 microseconds later.

An alternative interface treats the AD578 as a "slow memory" by starting the conversion with the falling edge of the Read signal, and then stretching the Read signal by inserting wait states until the 3 microsecond conversion time has elapsed.

DATA ACQUISITION SYSTEM WITH AD578



The high-speed AD578 can rapidly sample many channels. In many systems, auto-calibration can be performed by using Analog Ground and the AD578's reference voltage as two of the inputs to the analog multiplexer. The microprocessor can then measure the system gain and zero error (including S/H offset) and mathmatically correct for these errors.

MAXIM INTEGRATING A/D CONVERTERS

Device	Resolution	Sensitivity	Output
ICL7109	12 Bit + Sign	100 µV	Binary
ICL7106/16/26/36	3 1/2 Digit	100 µV	LCD
MAX136	3 1/2 Digit	100 µV	LCD
ICL7107/17/37	3 1/2 Digit	100 µV	LED
ICL7135	4 1/2 Digit	100 µV	Muxed BCD
ICL7129	4 1/2 Digit	10 µV	Triplexed LCD

MAXIM ADVANTAGE

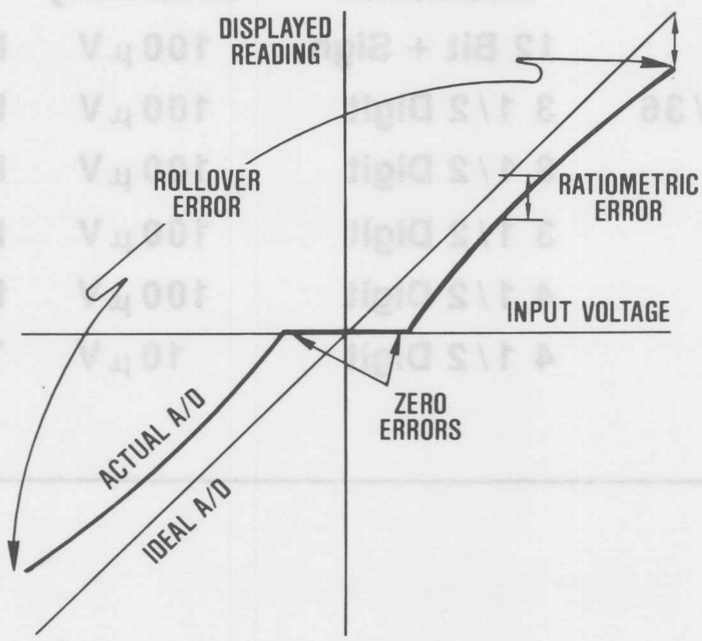
WHY USE AN INTEGRATING A/D?

- Low Cost
- Resolution and Accuracy Up to 16 Bits
- Excellent Differential Linearity
- High Normal Mode Rejection
- No Critical Component Values

Integrating A/Ds excel where high resolution, high accuracy, and low cost are required, and where relatively low measurement speed is acceptable. Typical applications are digital voltmeters and panel meters; pH, temperature, and pressure meters; weigh scales; and general purpose data loggers with sample rates up to 30 conversions per second.

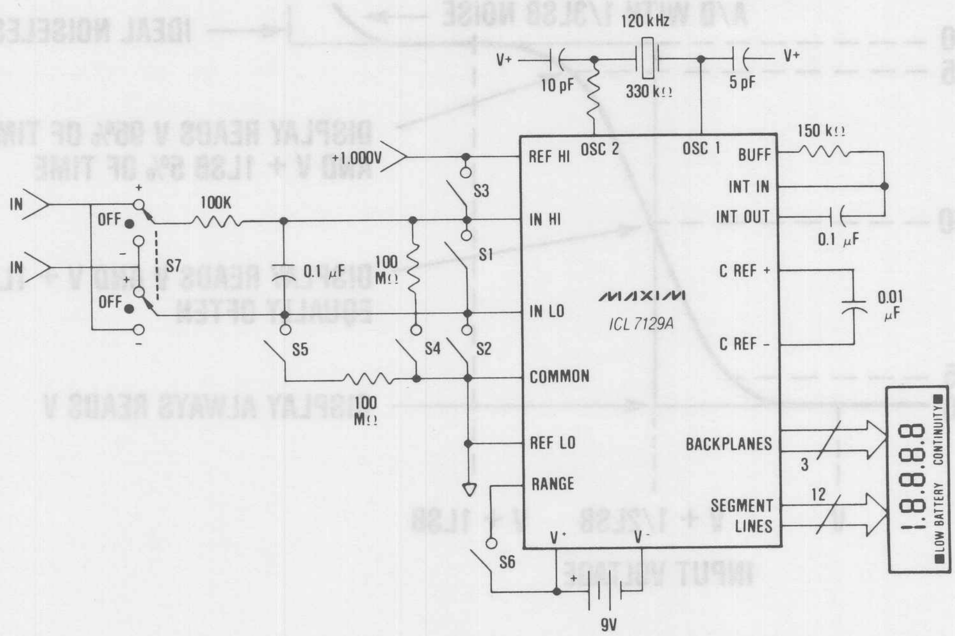
In many of these applications the clock frequency of the A/D is set such that the integration period is an integral multiple of the 50/60Hz power line or mains frequency. This results in normal mode or differential mode rejection of 80+ dB, as well as 120+ dB common mode rejection.

A / D TRANSFER FUNCTION



An ideal A/D would have a digital output which corrosponds exactly to its input voltage. Real A/Ds of course have finite resolution as well as integral and differential linearity errors. Integrating A/Ds have special terms associated with specific types of errors. -- Ratiometric error is the integral linearity error with a positive input voltage equal to the reference voltage. Rollover error is the difference in magnitude of the readings for equal voltages near positive and negative full scale. Zero errors can be described as a zero offset which shifts the entire transfer curve up or down; or as zero width errors where the transfer function has a discontinuity as it passes through zero.

A/D TEST CIRCUIT

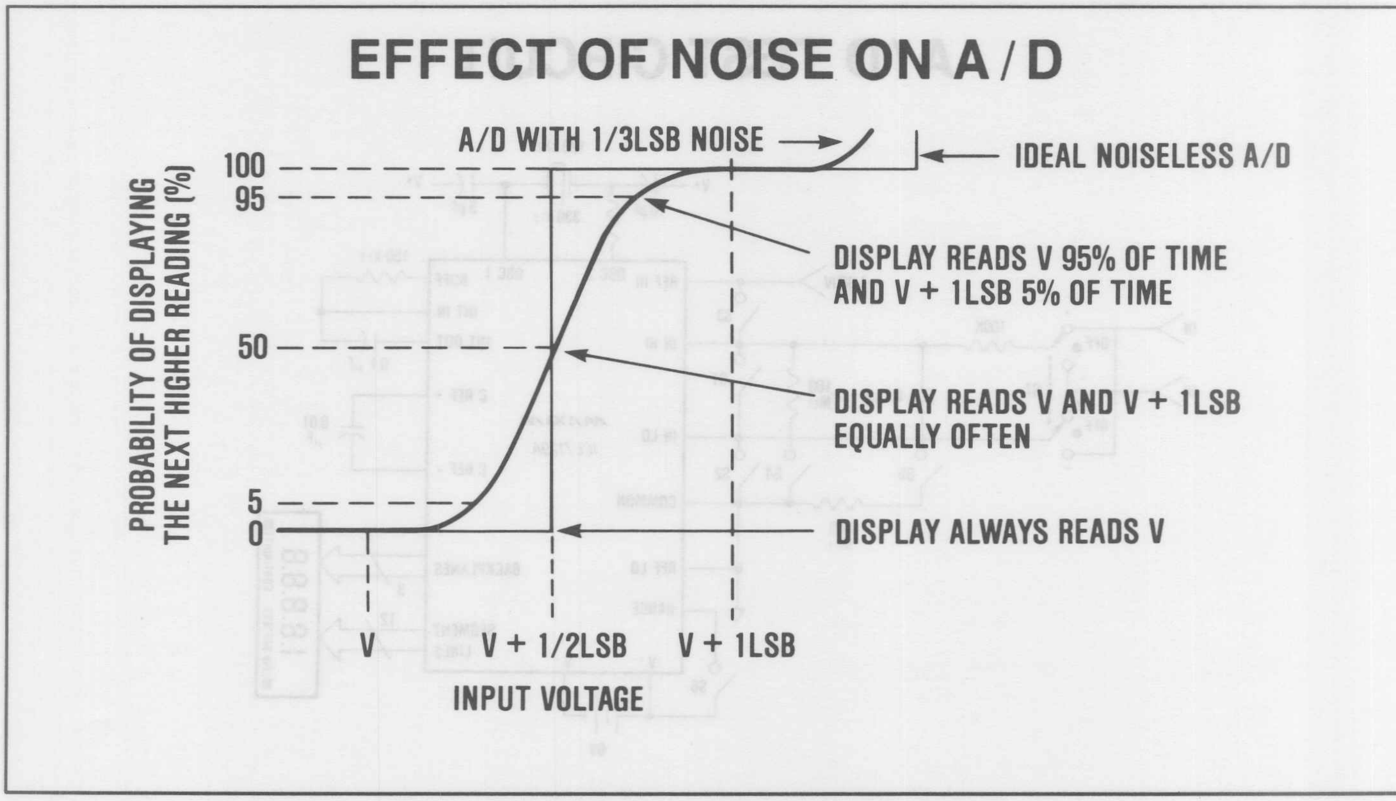


Fortunately, the testing of integrating A/Ds does not require complicated hardware. This relatively simple circuit can test each of the parameters just discussed.

TABLE OF SWITCH SETTINGS FOR A/D TEST CIRCUIT

	S1	S2	S3	S4	S5	S6	S7	Input Voltage	Measure
Zero Reading	X	X	O	—	—	—	O	—	Display should read + 0000 or −0000
Ratiometer Error	O	X	X	O	—	X	O	—	Display reads 9998 to 10,000
Rollover Error	O	X	O	O	—	O	±	≈199mV	Rollover error is difference in reading as S7 reverses the input voltage polarity
In Hi Input Leakage	O	X	O	X	—	O	O	—	Leakage in pA = reading ÷ 10
In Lo Input Leakage	O	O	O	O	X	O	O	—	Leakage in pA = $\frac{\text{reading}}{10}$
Common Mode Rejection Ratio	X	O	O	O	—	O	±	V_{CM}	Display should read ±0000 for $V_{CM} < 3V$
Linearity	O	X	O	O	—	—	±	O to full scale in 0.1FS increments	Measure input V w/ 5½ digit meter compare w/ displayed reading
Zero Code width	O	X	O	O	—	O	±	≈95uV	Find ±0009 to ±0010 transition
Noise	O	X	O	O	—	—	±	Near 0V and full scale	Measure width of transition band where display shows two adjacent readings

X = Closed O = Open — = Don't care



This graph is an expanded view of the A/D transfer function, showing just 1 count of the entire ±20,000 count range of the ICL7129A. The ideal A/D would have a staircase transfer function with a sharp transition between adjacent displayed codes. A real A/D, however, shows the effect of noise by sometimes displaying an adjacent code.

The noise of integrating A/Ds has traditionally been specified using the phrase "noise not exceeded 95% of the time". This is measured by carefully adjusting the input voltage until the display shows one reading (V for example) for 95% of the conversions, and the adjacent reading (V+1LSB) for 5% of the conversions (once every 10 seconds at the 2 conversion/second reading rate of the ICL7129A). Note and record this voltage. Now adjust the input voltage until the A/D displays V+1LSB for 95% of the conversions and V for 5% of the conversions. The "not exceeded 95% of the time" noise is the difference between this input voltage and the first input which you recorded. This noise measurement method is used by Maxim for design engineering characterization of A/Ds.

An alternate noise measurement technique more suitable for ongoing QA screening is to step the input voltage in 1/10 count (LSB) steps. Observe the display for approximately 10 or 20 conversions at each input voltage step, noting at how many of the steps the A/D display flickers between adjacent counts. A perfect A/D will show only one value for any given input. An A/D with noise of approximately 1/2 count will have a stable reading on 5 of the 10 input voltage steps and will flicker between adjacent readings on 5 of the 10 input voltage steps. An A/D with noise greater than 1 full count will flicker on all 10 voltage steps, and will show three different readings for one input voltage at some of the input voltage steps. This method is used by Maxim's QA department to sample test the noise of A/D lots on an ongoing basis.

MAXIM ADVANTAGE

NOISE REDUCTION TECHNIQUES

- ICL7129A Commutation Reduces 1/f Noise
- ICL7652 Preamp Raises Signal to 2V Full Scale
- Digital Averaging and Filtering
- Careful Circuit Design to Avoid Degradation of A/D Performance

The noise of an A/D can be reduced by increasing the signal level with a low noise amplifier such as the ICL7652. This is often used to convert thermocouple or strain gauge signals from a 1uV/count signal up to a 100uV/count signal.

The ICL7129 commutates both the inputs and the outputs of the first differential pair of its buffer and integrator to both reduce offset and 1/f noise. Any low frequency noise or offset first adds to the voltage on the integrator capacitor, then subtracts when the inputs and outputs are commutated. By making the two phases equal, offset and low frequency 1/f noise are cancelled out.

MAXIM ADVANTAGE

COMPONENT SELECTION FOR A/Ds

Integrator Capacitor

- Low Dielectric Absorption - Polypropylene
- Polyester (Mylar™) Causes ≈ 0.1% Nonlinearity

Auto Zero Capacitor

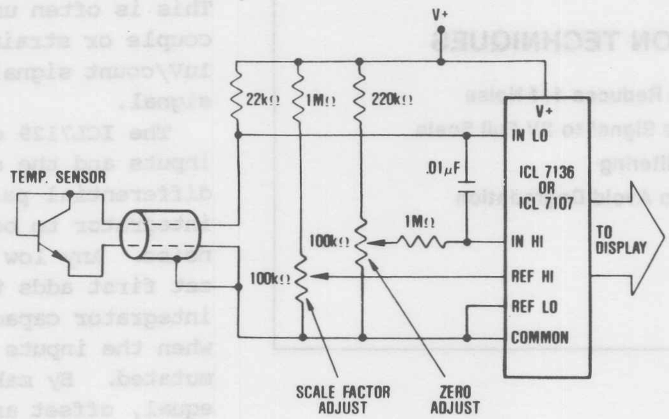
- Low Leakage - Almost Any Film Capacitor

Reference Capacitor

- Low Leakage
- Low Dielectric Absorption if Reference Voltage Changes

MAXIM ADVANTAGE

LOW COST TEMPERATURE METER

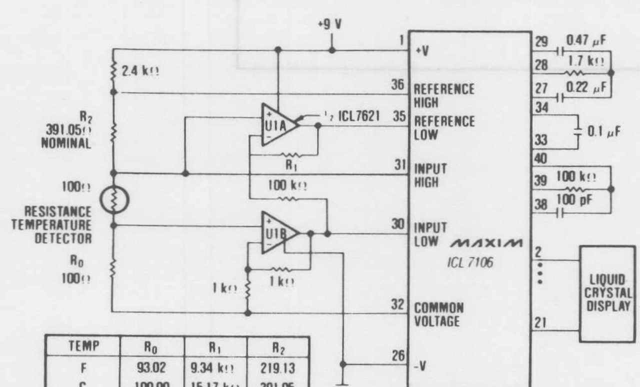


This low cost meter depends upon the -2.2mV/^{o}C temperature coefficient of the V_{BE} of a diode-connected silicon NPN transistor. Adjust the Zero Adjust potentiometer after placing the sensor in a 0^{o}C ice bath. Then raise the sensor temperature to the upper end of the temperature range and adjust the Scale Factor potentiometer until the correct reading is observed.

For a limited temperature range, a single point calibration is sufficient: set the reference voltage to 220mV with the Scale Factor Adjust then adjust Zero until the correct temperature is displayed. If the temperature coefficient of the sensor transistor has been measured, set the reference voltage to 100 times its V_{BE} change per ^{o}C.

MAXIM ADVANTAGE

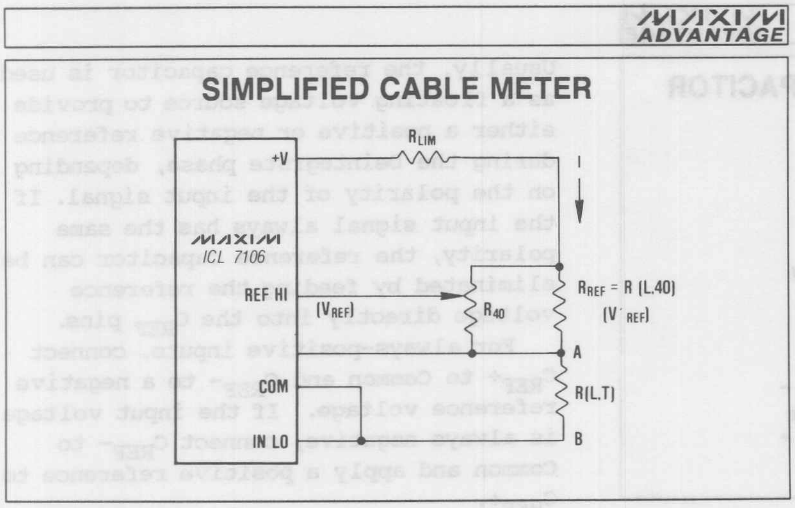
RTD TEMPERATURE METER



TEMP	R_0	R_1	R_2
F	93.02	9.34 kΩ	219.13
C	100.00	15.17 kΩ	391.05

The common platinum resistance sensor (also called PT100, RTD, or PRT) is a repeatable, stable, and reliable sensor. It is, however, nonlinear. This circuit compensates for the nonlinearity by adding a correction signal to the reference voltage via the op-amp U1A.

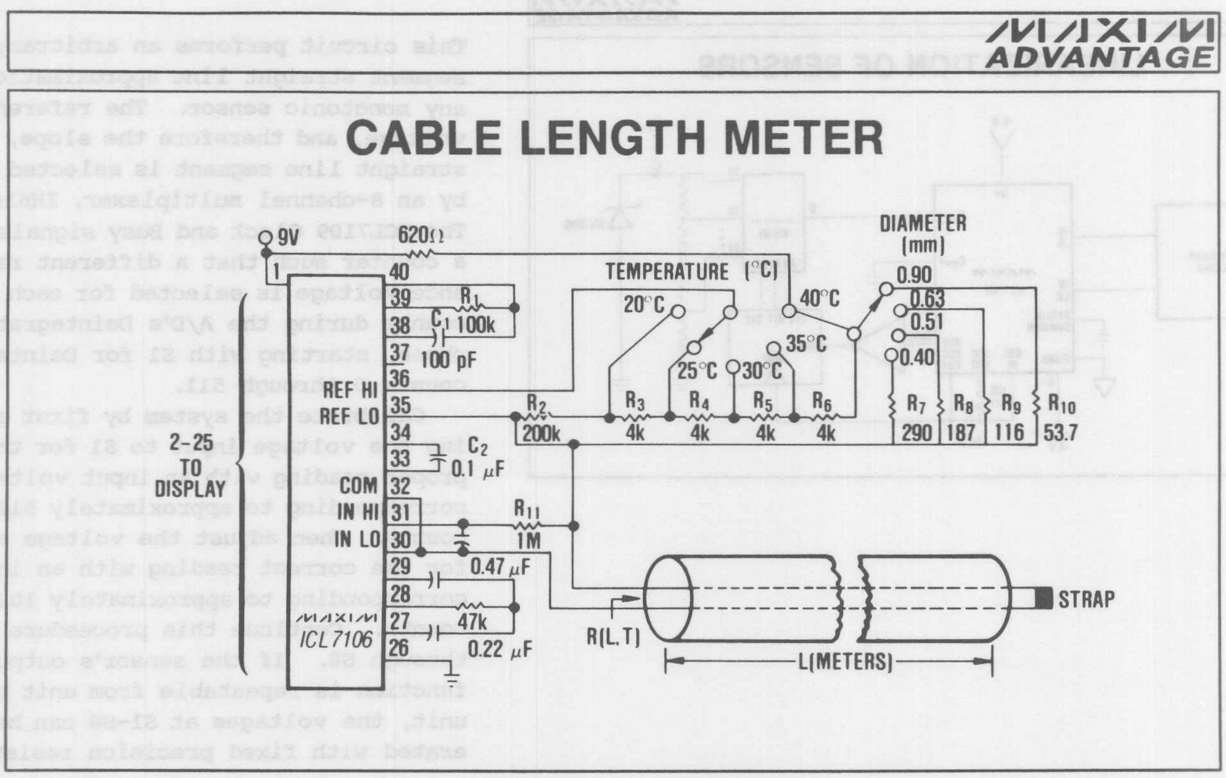
Op amp U1B provides a zero offset correction by making the voltage at Input Low equal to the voltage at Input High when the RTD resistance is equal to that of R_0. Since the ICL7136 is used in the ratiometric mode, no voltage reference is needed.



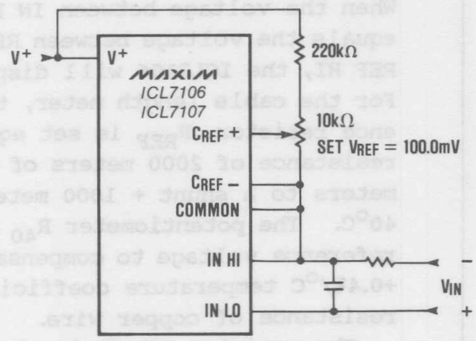
The upper schematic is a simplified diagram of ratiometric ohms measurement. When the voltage between IN LO and IN HI equals the voltage between REF LO and REF HI, the ICL7106 will display 1000. For the cable length meter, the reference resistor, R_{REF} is set equal to the resistance of 2000 meters of cable (1000 meters to a shunt + 1000 meters back) at 40°C. The potentiometer R_{40} reduces the reference voltage to compensate for the +0.4%/°C temperature coefficient of the resistance of copper wire.

The resistor R(L,T) is the cable whose length is being measured. A strap or shunt is placed at the far end, and the near end is connected to points A and B. The resistance between A and B is now a function of the cable length and temperature.

In the complete schematic, R7-R10 are selectable resistors which correspond to R_{REF} of the simplified schematic, R2-R6 correspond to R_{40}, and the cable itself is R(L,T).



OPERATION WITHOUT REFERENCE CAPACITOR

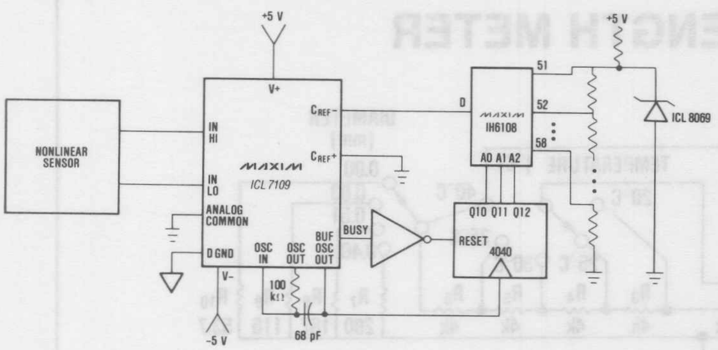


Usually, the reference capacitor is used as a floating voltage source to provide either a positive or negative reference during the Deintegrate phase, depending on the polarity of the input signal. If the input signal always has the same polarity, the reference capacitor can be eliminated by feeding the reference voltage directly into the C_{REF} pins.

For always-positive inputs, connect $C_{REF}+$ to Common and $C_{REF}-$ to a negative reference voltage. If the input voltage is always negative, connect $C_{REF}-$ to Common and apply a positive reference to $C_{REF}+$.

This circuit can also be used to perform a "1/X" function, where the displayed reading is inversely proportional to the voltage being measured. For 1/X readings, connect the voltage to be measured to the $C_{REF}-$ (+ or -) terminal, and feed a fixed negative reference voltage into IN HI. Typical applications include RPM meters and conductance meters.

LINEARIZATION OF SENSORS

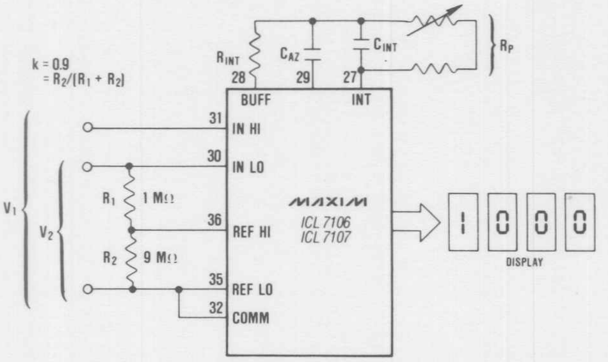


This circuit performs an arbitrary 8-segment straight line approximation of any monotonic sensor. The reference voltage, and therefore the slope, of straight line segment is selected by an 8-channel multiplexer, IH6108. The ICL7109 Clock and Busy signals drive a counter such that a different reference voltage is selected for each 512 counts during the A/D's Deintegrate phase, starting with S1 for Deintegrate counts 0 through 511.

Calibrate the system by first adjusting the voltage input to S1 for the proper reading with an input voltage corresponding to approximately 512 counts. Then adjust the voltage at S2 for the correct reading with an input corresponding to approximately 1024 counts. Continue this proceedure for S3 through S8. If the sensor's output function is repeatable from unit to unit, the voltages at S1-S8 can be generated with fixed precision resistors.

MAXIM ADVANTAGE

LOGARITHMIC RATIO

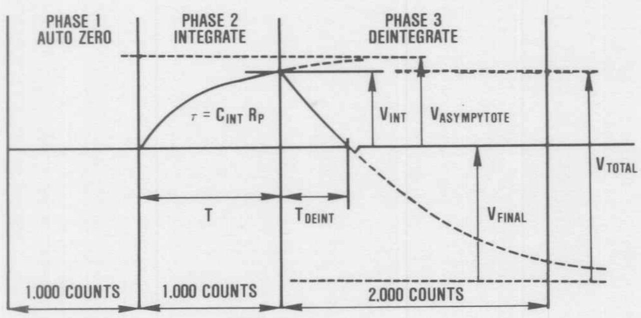


This circuit displays the logarithmic ratio of two input voltages, V_1 and V_2. The ratio of R1 to R2 should be precisely 1 to 9. Calibrate the circuit by adjusting R_P for a reading of 10.00 when V_1 = 10 V2.

Typical applications include, audio-level measurements, densitometry, and colorimetry.

MAXIM ADVANTAGE

LOG RATIO WAVEFORMS



The resistor R_P in parallel with the integrate capacitor makes the voltage waveforms on the capacitor exponential rather than the linear ramps of the normal configuration.

Unlike normal, linear operation, the accuracy of this circuit depends on both the ratio and the absolute value of the external components.

MAXIM ADVANTAGE

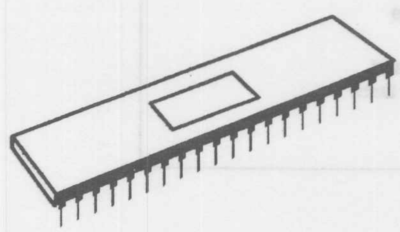
PRODUCT COMPARISON

Device	Maxim	Intersil	Teledyne
ICL 7106	✓	No Overload Recovery	No Overload Recovery
ICL 7107	✓	No Overload Recovery	No Overload Recovery
ICL 7126	✓	No Overload Recovery	No Overload Recovery
ICL 7136	✓	✓	Not Available
ICL 7109	✓	No Overload Recovery	No Overload Recovery
ICL 7135	✓	Higher Supply Current	Higher Supply Current
ICL 7129	✓	High Noise	Not Available

MAXIM
ADVANTAGE

QUALITY ASSURANCE

RELIABILITY



MAXIM ADVANTAGE

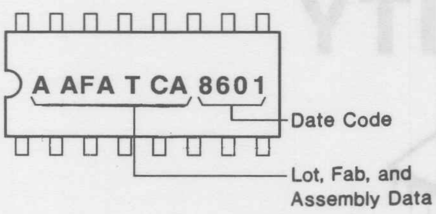
QUALITY ASSURANCE

- Conforms to Mil-I-45208A " Inspection System Requirements"
- Most of QA Systems Emulate Those Required by Mil-Std-883C
- Will Be Fully Compliant to Mil-Q-9858A "Quality Program Requirements" by May, 1986
- Full Traceability

MAXIM ADVANTAGE

TRACEABILITY

All Maxim Products Are Fully Traceable from Individual Product Back to Starting Material



MAXIM ADVANTAGE

ACCELERATED LIFE TESTING

- More Than 85,000 Devices Tested
- Every Manufacturing Lot Represented
- 192 Hours at 150°c
- Individual Product Reports Available

9 Failures Per Billion Device Hours

ENVIRONMENTAL TESTING

Pressure Pot

- Every Assembly Lot Sampled (Non-Hermetic Packages)
- Provides Control Gate for Integrity of Passivation and Assembly

85°C/85% Humidity

- Every Generic Device Type Evaluated on Regular Basis
- Test Time Is 1000 Hrs., with Extensions to 2000 Hrs.
- Excellent Correlation Between Pressure Pot & 85/85 Testing

MAXIM QUALITY ASSURANCE MANUAL

- QA Organization
- QA Policy and Responsibility
- Customer Spec. Review System
- Manufacturing Control
- Control of Procured Items
- Returned Material Procedure

LOT BUYOFF PROCEDURE

- Every Unit Shipped is Dispositioned by Quality Assurance Personnel
- Following Data Must Pass Acceptance Criteria:

  Test Yield
  Pressure Pot Results
  Life Test Results
  E.S.D. Evaluation
  Noise Characterization

- No Other Company Reviews this Data on a Per-Lot Basis!

MAXIM ADVANTAGE

NEW PRODUCT RELEASE PROCEDURE

Checklist Includes:

- Test Program Conforms to Data Sheet
- Life Test Results Acceptable
- Pressure Pot Results Acceptable
- E.S.D. Sensitivity - Every Pin >2000V
- Latch-Up Sensitivity - Every Pin Will Withstand 50mA Injected Current
- Noise Performance Acceptable (Where Appropriate)

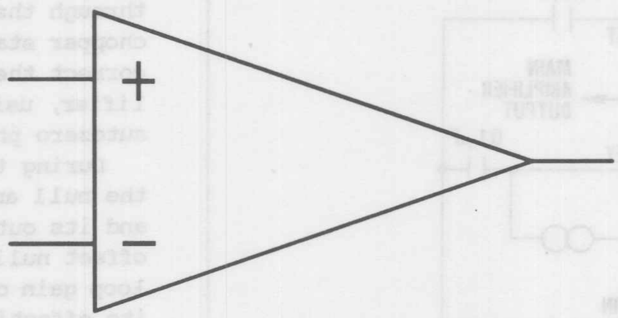
MAXIM ADVANTAGE

MAXIM'S HI REL (HR) PROGRAM

- Processing Emulates Screening Procedures Called Out in MIL STD 883C Method 5004
- Lot Qual Data Available (Group A,B,C, & D)
- Qualification and Traceability of All Raw Materials

MAXIM ADVANTAGE

OPERATIONAL AMPLIFIERS



- Chopper Stabilized
- Low Power
- Buffers
- Power Op Amps

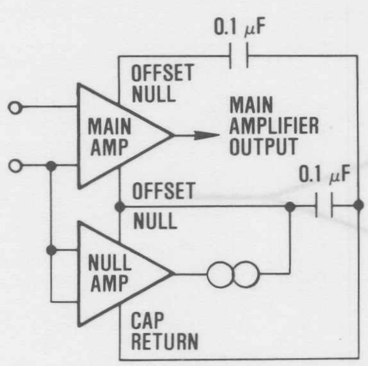
CHOPPER STABILIZED OP AMPS

- How Do They Work
- ±15V vs. ±5V Operation
- Thermocouple Preamplifier
- Strain Gauge Instrumentation Amp
- Measuring Current "Without" a Shunt
- Nulling a High Speed Op Amp

Maxim makes two families of chopper stabilized op amps. The ICL7650 and ICL7652 operate from ±2.25 to ±7.5V supplies. The MAX420/421/422/423 family operates from ±2.5V to ±16.5V supplies, allowing operation from standard ±15V analog power. Both families have 5uV guaranteed offset voltage and 50 nano-volts/°C offset voltage tempco!

Typical applications are strain gauge and thermocouple preamps, as well as other precision amplifiers which need very high gain and/or ultra-low offset voltage.

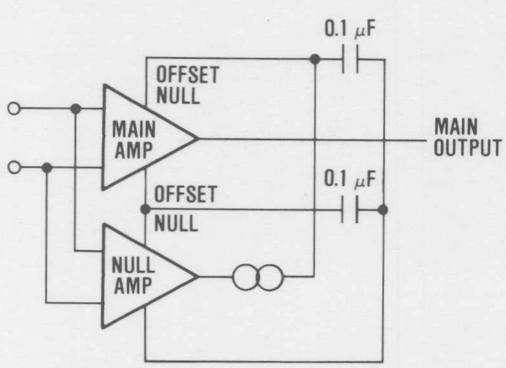
FIRST: NULL AMP NULLS ITSELF



Unlike older chopper amplifiers modules, chopper stabilized op amps are DC coupled. The signal passes directly through the main amplifier, while the chopper stabilization is used only to correct the offset of the main amplifier, using a technique similar to the autozero phase of integrating A/Ds.

During the first of the two phases, the null amplifier inputs are shorted, and its output connected to its own offset null adjust terminal. The open loop gain of the null amplifier reduces its effective offset to less than 1uV. The offset correction voltage is stored on an external 0.1uF capacitor.

THEN NULL AMP NULLS MAIN AMP



Now that the Null Amp has nearly zero offset, it monitors the voltage difference between the input terminals of the main amplifier. The Null Amp output drives the offset adjustment terminal of the main amplifier so that, through the external feedback network of the user's circuit, the input terminals of the Main Amp are driven so that they are exactly equal. The Main Amp's offset correction voltage is stored on a second external 0.1uF capacitor.

This two phase correction cycle is repeated 350 times per second by the internal oscillator, or at a user-selected rate via the external clock input.

MAXIM ADVANTAGE

MAX 420 Series
±15 Volt Chopper Stabilized Op-Amp

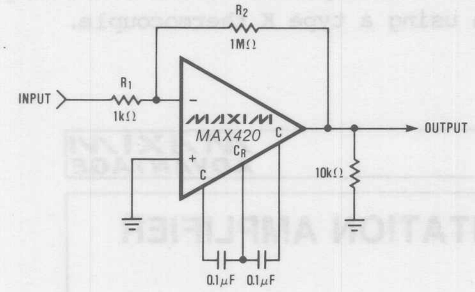
Features:

- 5μV Max Offset Voltage
- ±15V Supply Operation
- Input Voltage Range: +12V to -15V
- Low Input Noise: 0.3μV$_{p-p}$ (DC - 1Hz)
- High Gain, CMRR, PSRR
- Low Power CMOS Design: 0.5mA Max Supply Current
- Low Input Bias Current: 30pA Max

The MAX420 brings together the outstanding performance of the ICL7652 with the ease-of-use of ±15V supplies.

MAXIM ADVANTAGE

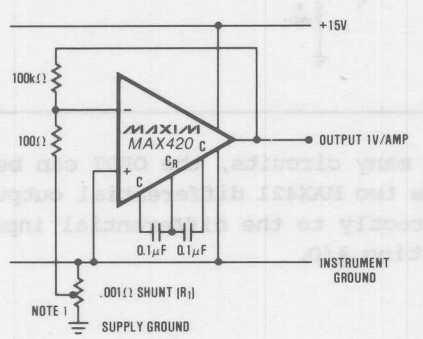
MAX 420 FAMILY
±15 Volt Chopper Amplifier



This simple circuit is a gain-of-1000 inverting amplifier. It will amplify sub-millivolt signals up to signal levels suitable for further processing. In almost all system applications it is best to use as much gain as possible in the MAX420, thus minimizing the effects of later-stage offsets. For example, if circuitry following the MAX420 has an offset of 5mV, the additional offset referred back to the MAX420 input (gain = 1000) will be 5uV, doubling the system's offset error.

MAXIM ADVANTAGE

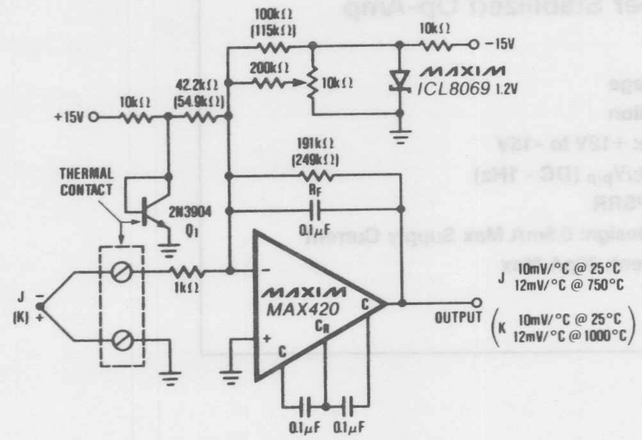
CURRENT SHUNT AMP
- Ultra Low Voltage Drop



This circuit measures the power supply current of a circuit without really having a current shunt resistor: R1 is only 3 centimeters of #20 gauge (0.8mm diameter) copper wire. A length of the power distribution wiring can be used for R1. The MAX420's CMVR includes its own negative power supply, therefore it can both be powered by and measure current in the ground line.

MAXIM ADVANTAGE

THERMOCOUPLE PREAMP

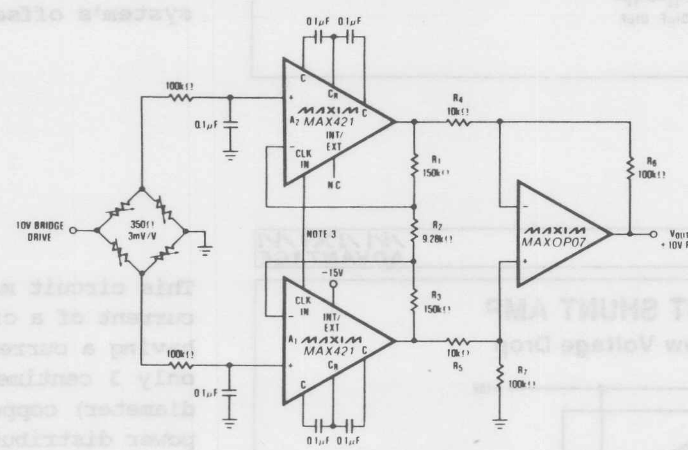


The MAX420 is operated at a gain of 191 to convert the 52uV/^{O}C output of the type J thermocouple to a 10mV/^{O}C signal. The -2.2mV/^{O}C tempco of the 2N3904 is added into the summing junction with a gain of 42.2 to provide cold junction compensation. The ICL8069 is used to remove the offset caused by the 600mV initial voltage of the 2N3904. Adjust the 10K trimpot for the proper reading with the 2N3904 and isothermal connection block at a temperature near the center of the circuit's operating range.

Use the component values shown in parentheses when using a type K thermocouple.

MAXIM ADVANTAGE

STRAIN GAUGE INSTRUMENTATION AMPLIFIER

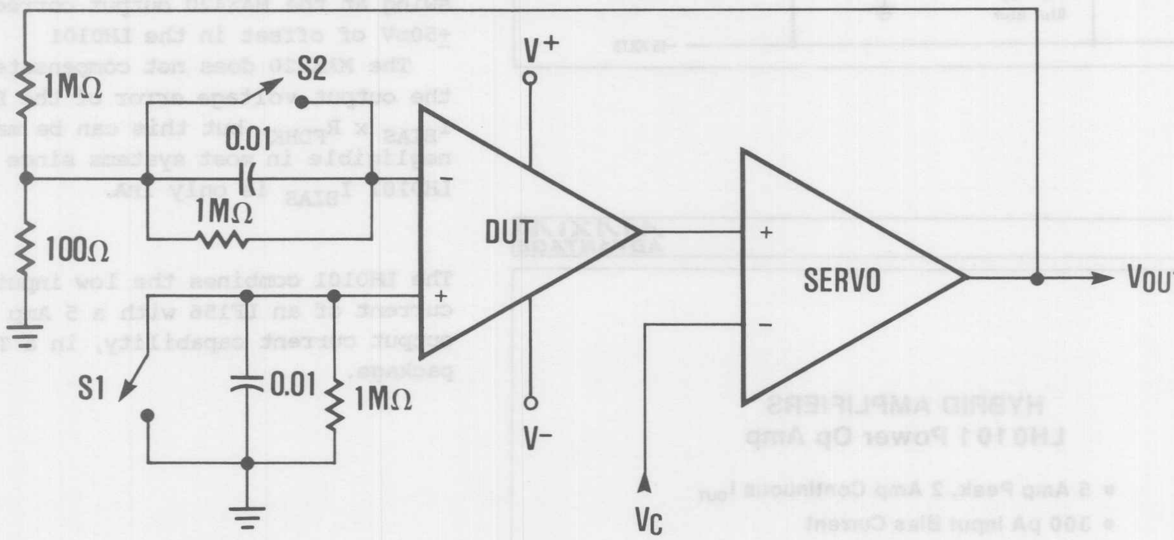


This circuit has an overall gain of 320. More gain can easily be obtained by lowering the value of R2. Untrimmed V_{OS} is 10uV, and V_{OS} tempco is less than 0.1uV/^{O}C.

In many circuits, the OP07 can be omitted, with the two MAX421 differential outputs connected directly to the differential inputs of an integrating A/D.

MAXIM ADVANTAGE

OP AMP TEST LOOP



This classic circuit can readily be used to measure MAX420 V_{OS}, PSRR, CMRR, and I_{BIAS}. The key to understanding the operation of this test circuit is to note that, when the loop is stabilized, the output of the servo amplifier is 10,000 times the input voltage of the Device Under Test (DUT), and that the output of the DUT is equal to the control input voltage at V_C.

With V_C = 0V, V^+,V^- = ±15V, and S1 and S2 closed; the voltage at V_{OUT} is the DUT V_{OS} x 10,000.

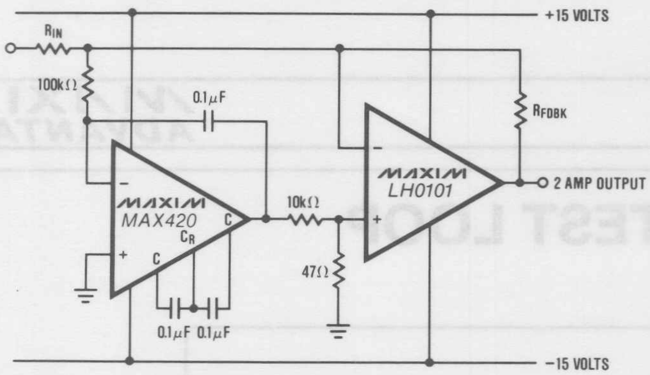
Since open loop gain (A_{VOL}) is the change in output voltage divided by the change in the input voltage required to swing the output, A_{VOL} can be found by measuring the change in V_{OS} as the control input, V_C, is varied to force a change in the DUT output.

Similarly, PSRR and CMRR can be determined by measuring changes in V_{OS} as V^+,V^-, and V_C are changed. For example, a +5V input common mode voltage can be simulated by setting V^+ = 10V, V^- = -20V, and V_C = +5V.

Bias current can be measured by measuring the change in V_{OUT} as switches S1 and S2 are opened.

MAXIM ADVANTAGE

LOW DRIFT HIGH SPEED POWER OP AMP



This circuit has the DC V_{OS} and gain characteristics of the MAX420, and the power handling and high speed AC characteristics of the LH0101.

The MAX420 monitors and integrates the offset error at the inverting input of the LH0101, then adjusts the non-inverting input such that the inverting input voltage is within 5uV of ground. The 10k/47 ohm attenuator between the MAX420 and the LH0101 input scales the offset adjustment range such that a $\pm$10V swing at the MAX420 output corrects for $\pm$50mV of offset in the LH0101

The MAX420 does not compensate for the output voltage error of the LH0101 $I_{BIAS} \times R_{FDBK}$, but this can be made negligible in most systems since the LH0101 I_{BIAS} is only 1nA.

MAXIM ADVANTAGE

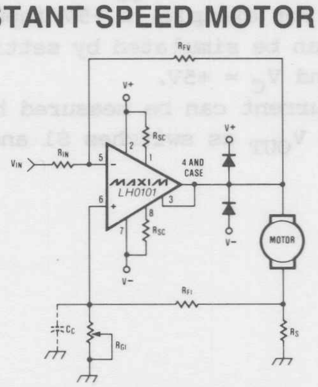
HYBRID AMPLIFIERS
LH0101 Power Op Amp

- 5 Amp Peak, 2 Amp Continuous I_{OUT}
- 300 pA Input Bias Current
- 5 MHz Gain Bandwidth Product

The LH0101 combines the low input bias current of an LF156 with a 5 Amp peak output current capability, in a TO-3 package.

MAXIM ADVANTAGE

CONSTANT SPEED MOTOR DRIVE



ADJUST R_G FOR BEST SPEED vs. LOAD REGULATION

When the torque load on the motor increases, its current increases. This current increase is sensed across R_S, and positive feedback is applied to the noninverting terminal of the LH0101, thereby increasing the motor voltage to compensate for the increased torque load. With the proper amount of positive feedback, the motor speed variation can be kept below 1% from no load to full load.

LH0033/LH0063/BB3553 BUFFERS

- 6000V/μS Slew Rate
- DC to 300MHz Bandwidth
- ±5V to ±18V Operation
- Pin for Pin 2nd Sources

These devices are popular for driving coaxial cables, distribution and buffering of video signals, and as buffers at the inputs of high speed flash A/D converters.

MAXIM ADVANTAGE

ICL 76XX
Low Power Op-Amps

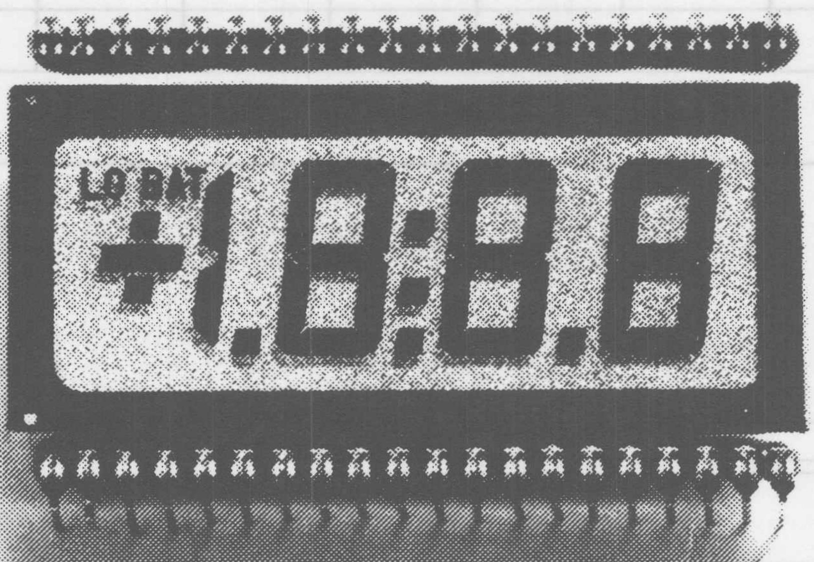
- CMOS - Flea Power Consumption
- CMOS - Out Performs Bi-Fet Amplifiers: I_{Bias} = 1.0 pA, I_{Offset} = 0.5 pA
- Singles, Duals, Triples, Quads
- Improved ESD Protection
- 100% Burn-in of All Parts

The ICL7611 family of CMOS op-amps are most often used in:

1) Battery powered systems where 10uA operating current is desired.
2) +5V only systems, where the rail-to-rail output swing and guaranteed low voltage operation are needed.
3) Applications such as photodiode transimpedance amplifiers and pH meters which require 1pA input bias current.

MAXIM ADVANTAGE

LCD DRIVERS COUNTERS TIMERS

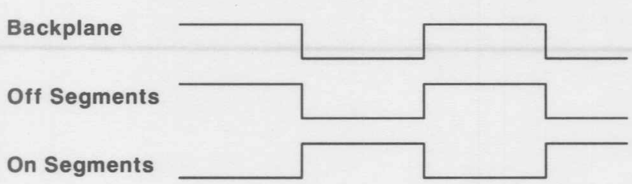


MAXIM
DISPLAY DECODER / DRIVERS

Device	4 Digit	8 Digit	10 Digit	4 Char	5 Char	LCD	LED
ICM 7211	X					X	
ICM 7212	X						X
MAX 7231		X				X	
MAX 7232			X			X	
MAX 7233				X		X	
MAX 7234					X	X	
ICM 7218		X					X

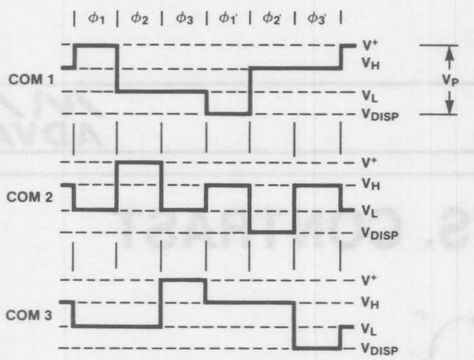
MAXIM ADVANTAGE

LCD DIRECT DRIVE WAVE FORMS



LCDs require an AC drive waveform since DC voltages in excess of 50mV will damage the displays. To turn ON a segment, LCD display drivers connect that segment to a signal that is 180° out of phase with the backplane drive signal. This results in an an AC voltage across the segments which is twice the display voltage. OFF segments are driven in phase with the backplane, and therefore have no AC voltage across them.

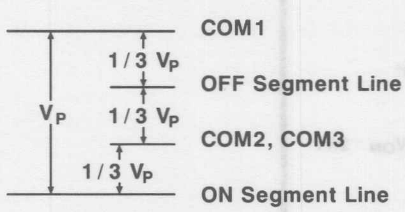
TRIPLEXED LCD WAVEFORMS



Triplexed LCDs have three backplanes, and every segment line drives three separate segments, one for each backplane. The backplane waveforms have 6 separate phases.

During each of the first three phases, one backplane is at the most positive voltage, while the other two are at the lower intermediate voltage, V_L. The remaining three phases are an inversion of the first three: the three backplanes are each connected to the lowest voltage, V_{DISP}, for one phase while the other two backplanes are at the higher intermediate voltage, V_H.

VOLTAGE LEVELS DURING ϕ1



OFF Segment

- 1 / 3 V_P to All Commons

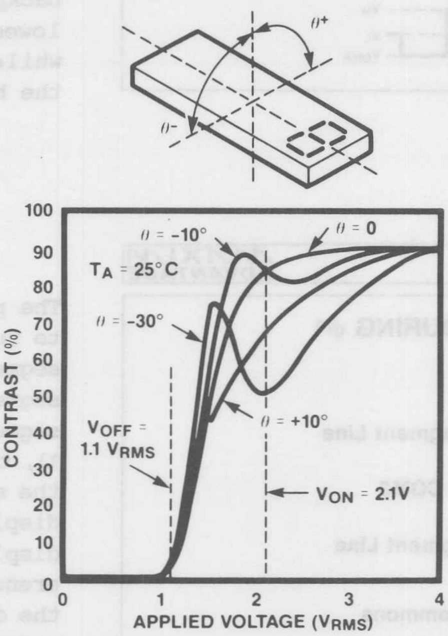
ON Segment

- V_P to COM1
- 1 / 3 V_P to COM2, COM3

The problem that must be solved is how to turn ON or OFF each of the three segments that are driven by a single segment drive line. To turn ON the segment referenced to COM1 (backplane 1), the LCD display driver will drive the segment drive line to the lowest display voltage. This applies the full display voltage across the segment referenced to COM1, but only applies 1/3 of the display voltage across the segments referenced to COM2 and COM3. This 1/3 display voltage is below the turn-on threshold of the display, so these segments are not turned ON during this phase.

If the segment referenced to COM1 is supposed to be OFF, the LCD display driver drives the segment line to the upper intermediate voltage level, thereby applying 1/3 display voltage to all three segments driven by the segment line.

DRIVE VOLTAGE VS. CONTRAST



If the waveforms shown in the previous two slides are analyzed, it can be shown that an ON segment has an RMS voltage applied which is 1.92/3 x V_{DISP}. The OFF segments are driven with an RMS voltage of $V_{DISP}/3$. This means that the ratio of ON to OFF voltage is 1.92 for a triplexed display.

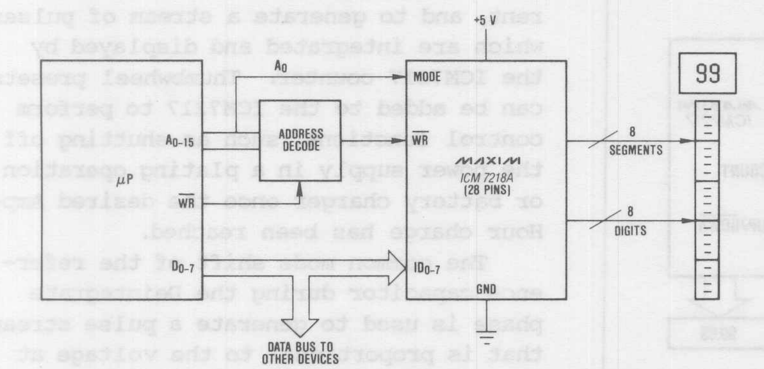
The ideal LCD fluid would have an RMS Drive Voltage to Contrast characteristic of 0% contrast up to the turn-on voltage and 100% for all voltages above the turn-on voltage. While actual LCD fluids do not have this "brick wall" characteristic, the abrupt change in contrast is sufficient for reliable operation with triplexed waveforms. With V_{DISP} = 3.3V, the OFF segments have 1.1V RMS applied and contrast of less than 10%. The ON segments have 2.1V applied and at least 50% contrast at all viewing angles (the different curves on the graph show the contrast for different viewing angles). A 16 row multiplexed LCD display, on the other hand, has only a 1.291 ON/OFF voltage ratio, and the ON segments would have less than 30% contrast using the LCD characteristic shown.

ICM 7218
8 Digit LED Driver

- 8 Digits of 7 Segments & D.P. or 64 Individually Controlled Segments
- HEX, Code B or No-Decode
- On-board Digit Drivers
- Low Power CMOS

The ICM7218 can accept and decode data either in BCD or HEX format, or can accept bit-mapped data with individual control of each of the 64 LED segments. In this circuit the no-decode mode is used to drive 50 LEDs configured as a bargraph, and 14 LEDs configured as a two digit 7-segment display. This circuit can display a quantity as both a 2% resolution analog display and as a 0 to 99 digital display.

ICM7218 DRIVES BARGRAPH AND DIGITS

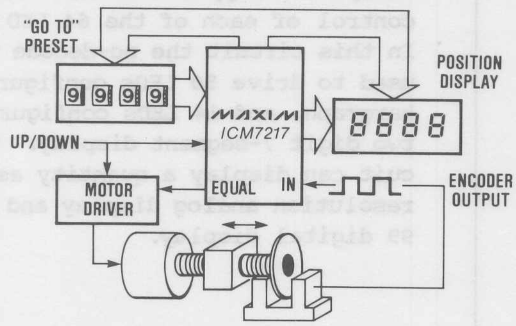


The Maxim ICM7218 is directly bus-compatible with most microprocessors. It has a minimum write pulse width of 200ns and data/address setup time of 250ns. While the ICM7218 uses only 5uA of current when shutdown, the onboard digit drivers supply 300mA of LED drive current.

MAXIM ADVANTAGE

POSITION CONTROLLER USING ICM7217

- Thumbwheel Preset
- Up-Down
- Direct LED Drive

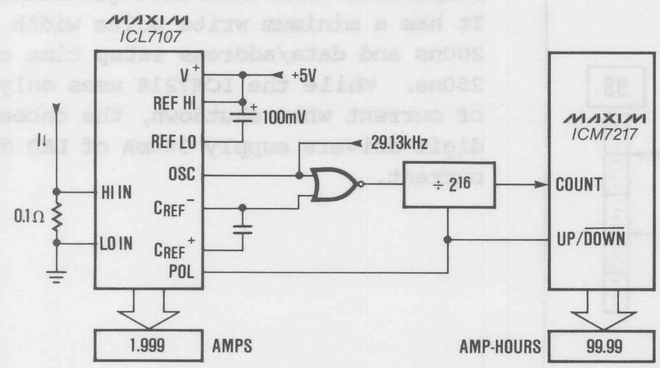


In this simplified block diagram the ICM7217 compares the desired position as indicated by the thumbwheel switch with the actual position as determined by the number of pulses generated by the incremental encoder. When the actual position equals the desired position, the ICM7217 Equal output turns off the motor driver.

More sophisticated controllers use a quadrature encoder to generate both Up and Down position pulses. With relatively simple input conditioning circuits the ICM7217 can count X1, X2 or X4 quadrature signals, or up-count and down-count signals, as well as operating with Count and Up/Down signals.

MAXIM ADVANTAGE

AMP-HOUR METER



This Amp-Hour meter uses the ICL7107 A/D to both display the instantaneous current, and to generate a stream of pulses which are integrated and displayed by the ICM7217 counter. Thumbwheel presets can be added to the ICM7217 to perform control functions, such as shutting off the power supply in a plating operation or battery charger once the desired Amp-Hour charge has been reached.

The common mode shift of the reference capacitor during the Deintegrate phase is used to generate a pulse stream that is proportional to the voltage at IN HI, and proportional to the oscillator frequency. The ICL7107 scale factor is set by the reference voltage and the 0.1 ohm resistor. The Amp-Hour scale factor can be adjusted by changing either the oscillator frequency or the 2^{16} prescaler.

MAXIM ADVANTAGE

MAXIM COUNTERS & TIMERS

- ICM 7555/7556
  CMOS Versions of 555 and 556 Timers
- ICM 7224
  4 1/2 Digit Counter w/ LCD Driver
- ICM 7225
  4 1/2 Digit Counter w/ LED Driver
- ICM 7217
  4 Digit Up/Down Counter w/ LED Driver,
  Preset/Compare Register
  Equal and Zero Outputs
- ICM 7240/42/50/60
  Long Range RC Timers with Counters
  Programmable Time Delays

MAXIM ADVANTAGE

ICM 7555/7556
Single & Dual RC Timers

Maxim Advantage Specs:

- Lower Supply Current - 120 μA vs. 200 μA
- Increased Output Source Current - 2.0 mA vs. 1.0 mA
- Improved ESD Protection
- 100% Burn-in

MAXIM ADVANTAGE

ICM 7240 FAMILY OF PROGRAMMABLE COUNTERS

- On-Board Programmable Counter

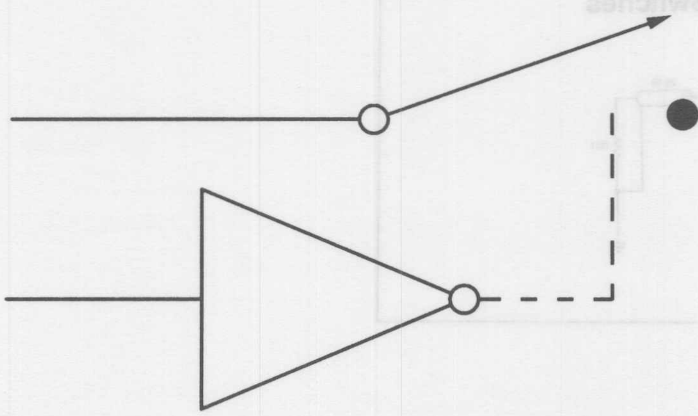
Device	Maximum Count	Format
ICM 7240	255	Binary
ICM 7250	99	BCD
ICM 7260	59	Horological
ICM 7242	128/256	Fixed

- Low Power CMOS - 120μA I_Q
- Programmable Divide-by-N Operation
- Cascadeable for Longer Delays

These counters combine an RC oscillator with an 8 bit, two digit, or modulo 60 counter. Typical applications are ON/OFF delay timers, ultra-long time delay generators, and programmable counters for electromechanical equipment. The time delay can be programmed using jumpers, DIP switches, or thumbwheel switches.

MAXIM ADVANTAGE

ANALOG SWITCHES



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IH5043 VS. CD4016

	IH5043	CD4016/66
Input Range	±15	±7.5V
Ron	75Ω	300Ω
Leakage	5nA	50nA
Level Shifters	Yes	No
Function	Single	Quad
	Dual	8 CH MUX
	Single Diff	4 CH Diff MUX
	Dual Diff	
	Quad	
	More	

The IH5040 has three major advantages over the CD4016 and CD4066:

1) The IH5040 has logic level translators, so the logic input range and the analog voltage range can be independently chosen.

2) The IH5040 will switch ±15V signals (CD4016 is limited to ±7.5V).

3) The IH5040 family has improved R_{ON} and leakage specifications.

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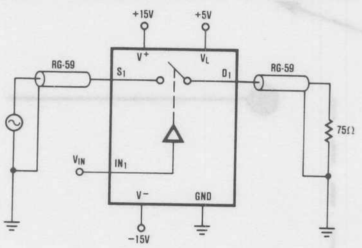
IH5341/5352
Dual/Quad Video Switches



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	IH5341/52	DG188/IH5040
10MHz Isolation	70dB MIN	30dB
10MHz Crosstalk	70dB MIN	20dB
Leakage	1nA	5nA
Ron	75Ω	75Ω

The IH5341 and IH5352 video switches excel in applications using 75 ohm or 50 ohm coaxial cable, and in those applications requiring high OFF isolation and crosstalk isolation up to 100MHz.

MAXIM ADVANTAGE

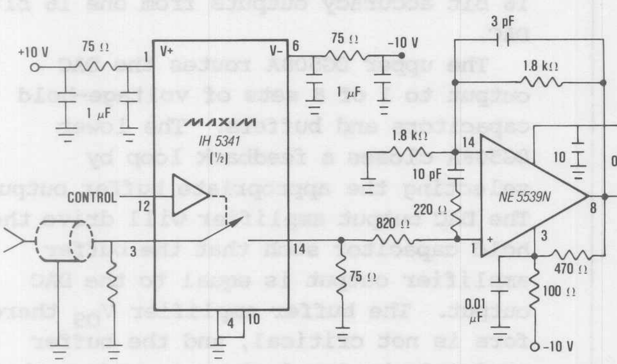
IH5341/5352
Dual/Quad Video Switches

Features:

- "OFF" Isolation ≥70dB @ 10MHz
- Cross Coupling Isolation ≥70dB @ 10MHz
- $r_{ds(on)}$ <75Ω
- ±5V to ±15V Operating Supply Range
- Supply Currents <1μA
- Fast, Break-Before-Make Switching (70ns/160ns typ.)
- <3dB Loss from DC to 100MHz

MAXIM ADVANTAGE

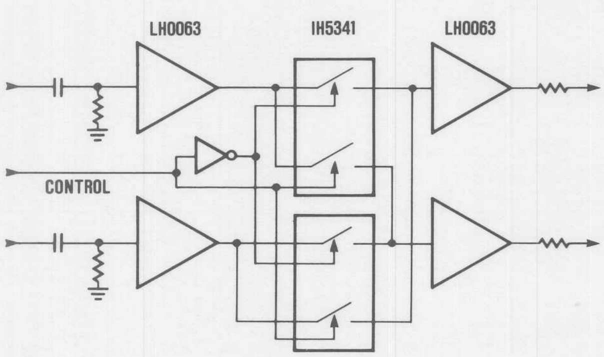
VIDEO SWITCH



This "lossless" video switch uses the NE5539 in a non-inverting gain of two (set by the 1.8 kilohm resistors) to restore the video signal level to its orignal amplitude. In many systems there is a 6dB loss in each coaxial cable since the signal source is back-terminated with a 75 ohm resistance and the receiving end of the coax is also terminated in 75 ohm.

MAXIM ADVANTAGE

LH0063/IH5341 VIDEO CROSSPOINT SWITCH

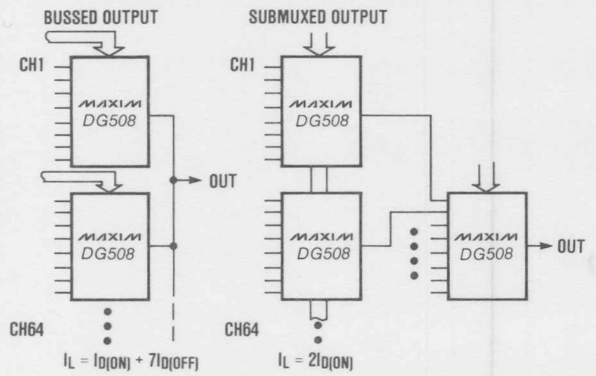


The IH5341 saves space and reduces component count in crosspoint video switches by replacing PIN diodes and their level translators.

The LH0063's 300MHz bandwidth and 50 ohm cable drive capability are well suited for video buffering applications such as crosspoint switches.

MAXIM ADVANTAGE

SUBMULTIPLEXING MINIMIZES LEAKAGE

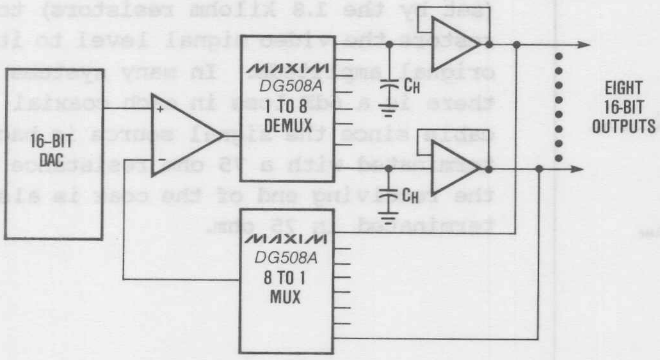


Recognizing that leakage current is a critical analog switch specification, Maxim guarantees an OFF channel leakage of only 0.1nA (only 1/100 of the industry standard spec) and ON channel leakage of 0.2nA (1/50 of industry standard spec). This may still be too much leakage current if many channels are bussed together as shown in the left side of this slide.

Submultiplexing as shown on the right hand side will reduce the total system leakage. Another benefit is that the digital interface is simplified since no chip enable decoders are needed.

MAXIM ADVANTAGE

DEMULTIPLEXING A 16-BIT DAC



Two DG508As can be combined with low cost buffer amplifiers to generate eight 16 bit accuracy outputs from one 16 bit DAC.

The upper DG508A routes the DAC output to 1 of 8 sets of voltage-hold capacitors and buffers. The lower DG508A closes a feedback loop by selecting the appropriate buffer output. The DAC output amplifier will drive the hold capacitor such that the buffer amplifier output is equal to the DAC output. The buffer amplifier V_{OS} therefore is not critical, and the buffer need only be low leakage to reduce the "voltage droop" while the other channels are being updated. The amplifier at the output of the DAC should be a high quality amplifier with both low V_{OS} and V_{OS} tempco.

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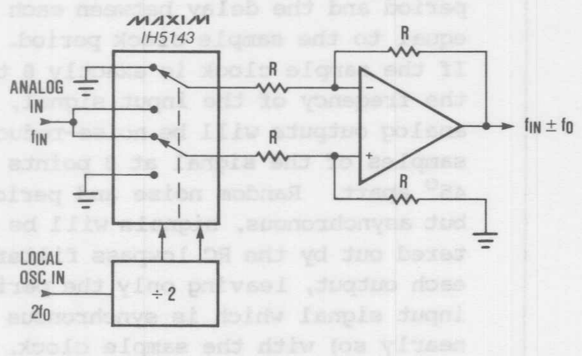
DOUBLE-BALANCED MIXER



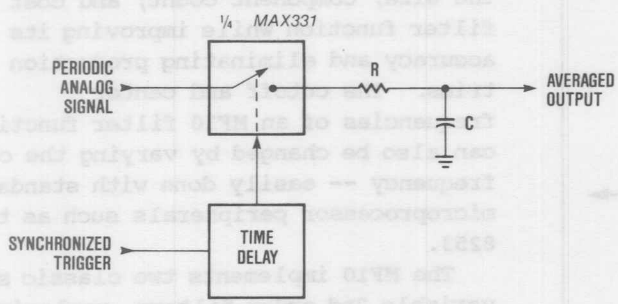
This simple circuit can be used for many different applications such as double sideband (DSB) modulators ($f_0 >> f_{IN}$), as well as synchronous detectors, and phase sensitive detectors ($f_0 = 2f_{IN}$).

The balanced digital drive circuit and the low charge injection of the IH5043 combine with a balanced op amp input circuit to provide greater than 60 dB local oscillator rejection.

Trim for maximum rejection by applying a DC signal to the input and trimming any one of the resistors for minimum local oscillator feedthrough.

MAXIM ADVANTAGE

SIMPLE BOXCAR AVERAGER

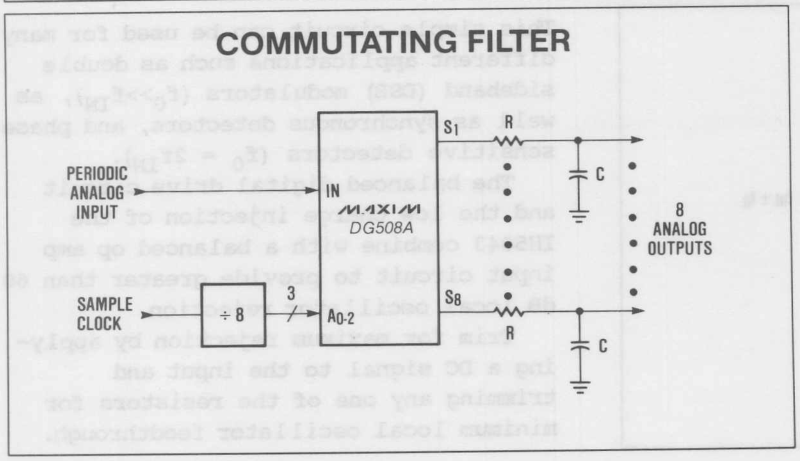


By closing the switch for only a short sampling period, at exactly the same point in each cycle of the input waveform, the capacitor is charged to the voltage of the periodic input waveform at the sampling point. Random or periodic, but asynchronous, signals do not charge the capacitor since their average voltage is zero. This circuit can therefore generate a relatively noise-free sample of a signal "buried" in noise.

The signal-to-noise improvement is 2RC/T, where T is the period for which the switch is closed. The circuit must sample for 5RC x T x F to settle within 0.7% of the final value, where T is the sampling period and F is the sampling frequency.

A low-noise reconstruction of a noisy signal can be recovered by slowly increasing the time delay between the trigger and the sample period.

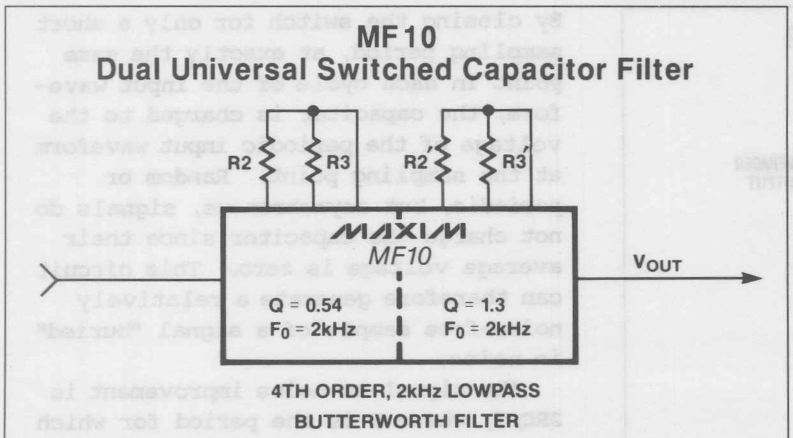
MAXIM ADVANTAGE



This circuit is similar to 8 boxcar averaging circuits with the sampling period and the delay between each stage equal to the sample clock period.

If the sample clock is exactly 8 times the freqency of the input signal, the 8 analog outputs will be noise-reduced samples of the signal at 8 points spaced 45^{o} apart. Random noise and periodic, but asynchronous, signals will be filtered out by the RC lowpass filters on each output, leaving only the periodic input signal which is synchronous (or nearly so) with the sample clock.

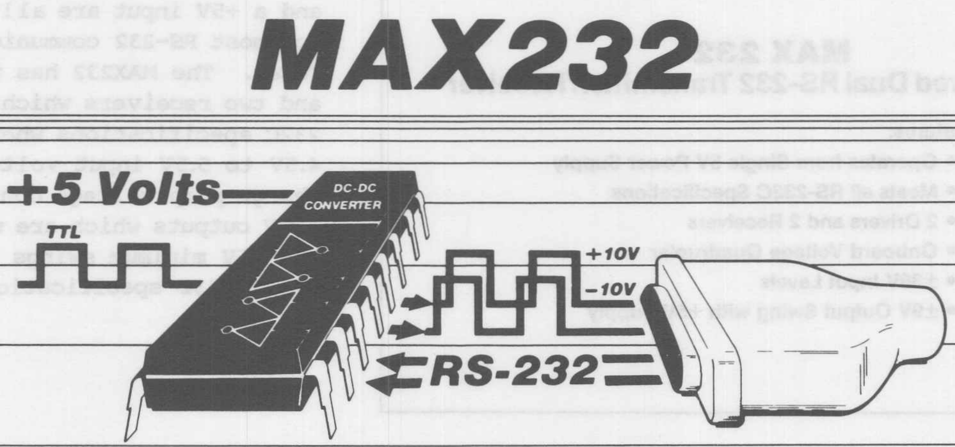
MAXIM ADVANTAGE



In many applications the MF10 switched capacitor filter significantly reduces the size, component count, and cost of a filter function while improving its accuracy and eliminating production trims. The cutoff and center frequencies of an MF10 filter function can also be changed by varying the clock frequency -- easily done with standard microprocessor peripherals such as the 8253.

The MF10 implements two classic state variable 2nd order filters, replacing most of the resistors with on-chip switched capacitors. The MF10 also requires no external capacitors.

MAXIM ADVANTAGE



MAXIM ADVANTAGE

RS-232 OUTPUT FROM 5V

DC-DC Converter Module + MC1488 + MC1489

Or...

ICL7660 + ICL7660 + MC1488 + MC1489

Or...

MAX631 + MC1488 + MC1489

Or...

MAX232

Until Maxim introduced the MAX232, the system designer of a +5V powered system had limited options for powering an RS-232 output: he could "cheat" and send 0V to +5V signals and hope that it worked; he could purchase an expensive DC-DC converter module and power an MC1488 from ±12; or he could use one or more ICL7660s, but usually had to build his own level translators since the MC1488 draws significant power.

MAXIM ADVANTAGE

MAX 232

+5V Powered Dual RS-232 Transmitter/Receiver

Features:

- Operates from Single 5V Power Supply
- Meets all RS-232C Specifications
- 2 Drivers and 2 Receivers
- Onboard Voltage Quadrupler
- ±30V Input Levels
- ±9V Output Swing with +5V Supply

The MAX232, 4 low cost 22uF capacitors, and a +5V input are all that is required for most RS-232 communication interfaces. The MAX232 has two transmitters and two receivers which meet all EIA RS-232C specifications when operated from a 4.5V to 5.5V input voltage. Two onboard charge pump voltage converters generate ±10V outputs which are used to develop the ±5V minimum swings required by the EIA RS-232 specification.

MAXIM ADVANTAGE

RS-232C SPECIFICATIONS

Output Swing, 3KΩ Load	±5V Min
Output Swing, Open Circuit	±15V Max
Slew Rate	30V/μs Max
Input Threshold	±3V Max
Max Input Voltage	±25V
Input Resistance	3KΩ to 7KΩ

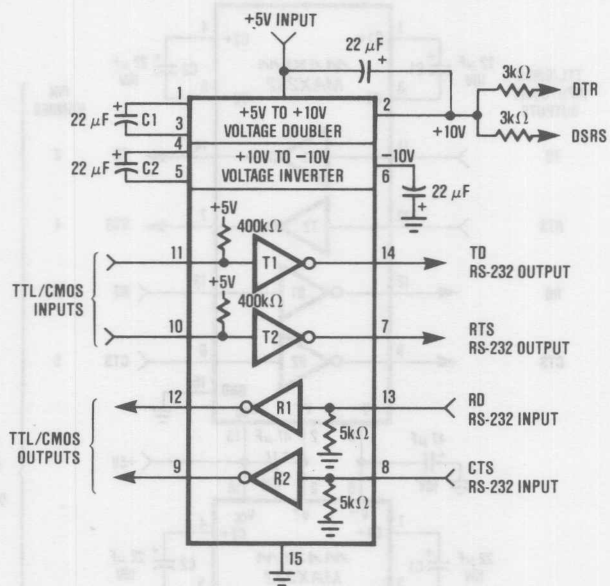
MAX232 Meets or Exceed All RS-232 Specifications over Temperature and Vcc = 5V± 10%

The RS-232 specification calls for a 2V logic noise margin: the transmitters must deliver at least ±5V swing, while the receivers must respond to signals which swing ±3V. The slew rate is specified at a maximum of 30V/us to reduce ringing and reflection problems, while the receiver input impedance is specified to be between 3 kilohms and 7 kilohms to provide a known terminating impedance.

RS-423 has similar specifications, but the slew rate is programmable for very high (>38kbaud) data rates. Except at very high data rates, RS-232 and the MAX232 is compatible with RS-423.

MAX 232

Dual RS232 Transmitter/Receiver



This simple circuit implements a duplex RS-232 port with CTS/RTS handshaking. DTR is active whenever the MAX232 is powered. Other fixed output signals such as DSRS (data signaling rate select) can also be generated by driving them through a 3k resistor connected to V^+.

Combining Two MAX232s